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THE EFFECTS OF IMMATURITY AND ARTIFICIAL DRYING UPON THE QUALITY OF SEED CORN

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THE EFFECTS OF IMMATURITY AND ARTIFICIAL DRYING UPON THE QUALITY OF SEED CORN

INTRODUCTION

In the production of corn for seed use, the maturity of the ears at harvest has an important relation to the quality of the product. This is equally true whether the corn is dried naturally or artificially. At the present time a large proportion of the seed corn crop produced in Canada is conditioned for storage by the use of heated air under forced draft. Immediately after harvest the corn is dried on the ear in specially constructed driers at temperatures which cause little or no damage to the viability of seed that has reached normal maturity, at which time it contains approximately 35 per cent of moisture. In almost every year, however, for various reasons some portion of the seed crop fails to reach maturity and is harvested in an immature condition. It was to obtain information regarding the effects of immaturity and artificial drying upon the quality of seed corn that this investigation was conducted.

In Canada, corn normally contains a much higher percentage of moisture at the time of harvest than other cereal grains. Corn is a full season crop. It is generally planted in May and is usually harvested in October. The choice of variety and the nature of the season are the principal factors which determine what the moisture content of the corn will be at harvest time. Other things being equal, the earlier the variety the lower the moisture in the corn.

In most seasons the kernel moisture content of the ears of adapted varieties averages from 25 to 35 per cent at the usual harvest time. In very favourable years it may drop below 25 per cent, while in less favourable seasons it may vary up to 45 per cent. Ears of late, unadapted varieties may contain more than 45 per cent of moisture in the kernel. Reducing the moisture quickly to 14 per cent or slightly lower, so that the seed can be shelled and stored safely presents a problem. To accomplish this a number of driers have been erected in recent years, where the corn for seed is processed by the use of artificial heat.

There are two important factors to be considered in the artificial drying of seed corn. One is the temperature to be employed and the other is the stage of maturity of the ears that are to be dried, for in the drying process it is essential that in addition to conditioning the seed for safe storage, no harm be done to either its germination or its vitality. Bearing in mind these factors it is obvious that for practical and economical reasons the moisture content of the corn should be reduced as quickly as possible. As the result of investigation and actual experience it has been found that by drying at temperatures ranging from 105°F. to 110°F. little or no harm is done to corn that has reached normal maturity at harvest.

In this investigation studies were made of the effects of maturity and artificial drying on seed corn in which the different samples ranged from approximately 20 to 58 per cent of moisture in the kernels at harvest. At the lower of these levels the corn had dried considerably since maturity, while at the higher level it was decidedly immature. The time of drying varied from 2 to 32 days and the temperatures used ranged from 108°F. to 150°F. In order to ascertain the effects of artificial drying, observations were made on comparable air-dried samples in all phases of this investigation.

Materials and Methods

Ears of the yellow dent variety of corn, Minnesota No. 13, were harvested at different stages of maturity and designated as well matured, glazed, dough and milk. Tests which were made immediately after harvest showed that the amounts of moisture in the kernels were respectively, 27, 32, 42, 48 and 58 per cent.*

One hundred ears were harvested at each stage of maturity, 10 of which were chosen at random to provide composite kernel samples for the moisture determinations. The remaining 90 ears were divided at random into two lots of 45 ears each. One of these two lots was air dried while the other was artificially dried by treating with heat. Figure 1 shows typical kernels at each of the five stages of maturity.

Additional ear samples of Minnesota No. 13 were harvested at different stages of maturity from time to time, and used for separate studies.

Hand-pollinated ears of 36 inbred lines, as well as 32 single-cross hybrids and 32 double-cross hybrids, obtained by various combinations of the 36 inbreds, were harvested at different dates to provide samples containing approximately 20, 30, 40 and 50 per cent of moisture in the kernels. Harvesting dates were determined by taking ears from the plots at intervals and testing for moisture immediatly. Six ears were harvested of each inbred at the four moisture levels, 3 of which were air dried and 3 artificially dried. Each sample of the single and double crosses consisted of 10 ears at the four moisture levels. The ears of each of these samples were broken in half and 10 half ears, consisting of tip and butt halves of alternate ears, were air dried, while the other 10 half ears were artificially dried. Altogether, one hundred and forty 6-ear samples of the inbreds, and two hundred and sixty 10-ear samples of the single- and double-cross hybrids were treated in this manner.

Moisture determinations were made in a Brown-Duvel moisture tester. In Minnesota No. 13, composite kernel samples for moisture were obtained by removing four rows of kernels the entire length of the ear in each of the 10 ears chosen for this purpose. In the inbreds, single crosses, and double crosses, moisture percentages were obtained by using composite kernel samples taken lengthwise from 3 or 4 ears at each time of testing.

Air drying was done by placing the ears in open trays, arranged in a rack, in a well-ventilated room.

Artificial drying was done in a Freas thermo-electric horizontal flow, mechanical convection oven (Serial No. 641-21). The maximum air displacement was 250 cubic feet per minute, with a velocity of 350 linear feet per minute. The ears were placed in trays made of fine mesh wire which permitted the air to circulate around them freely. The drying temperature was set at 108°F., thermostatically controlled within a variation of 3°F.†

After drying, both the air-dried and artificially-dried ears were placed in bags and stored in a room which was maintained at an average temperature of 68° to 70°F.

Germination tests were made either by the rag doll method or in germinator pans, while seedling emergence tests were made in greenhouse flats.

Enzyme determinations were made by using the Hawk and Bergeim(12) method, with some slight modifications.

The investigations reported herein were carried on mainly during the years 1941, 1942 and 1943.

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*The kernel moisture contents are used frequently throughout the text as an indication of the relative maturity of the ear samples.

†For simplicity the artificial drying temperature is referred to throughout this paper as 108°F. Actually it should be 108° ± 1.5°F.

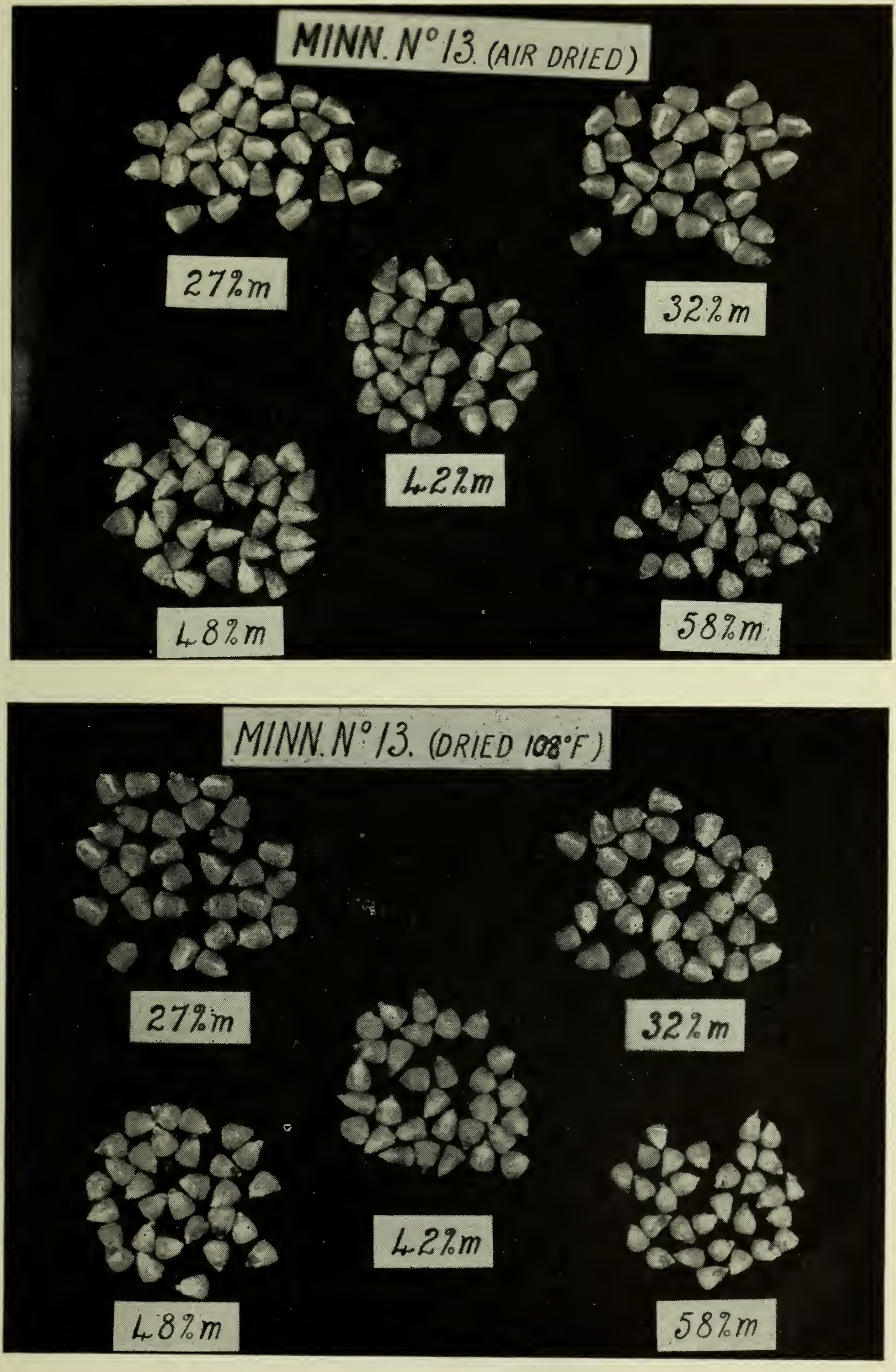

Fig. 1. Air-dried and artificially-dried kernels of Minnesota No. 13 corn which contained 27, 32, 42, 48 and 58 per cent of moisture at harvest.

Comparison Between Drying in a Commercial Bin Drier (Wisconsin Type) and Drying in a Freas Oven Drier

To determine whether the drying of small samples of ear corn in a Freas oven was comparable with the drying of ears in large quantities in a commercial bin drier, samples of ears of five commercial hybrids and three open-pollinated varieties, varying in maturity from very early to very late, were dried in both types of driers. All samples consisted of 10 ears selected at random from field plots at the normal harvest time. The bin-dried ears were placed in the centre of a bin which was filled with other ears. The size of the bin was 5 x 5 x 10 feet.

Both driers were operated at the same temperature, 108°F., and the ears were allowed to dry in the bin for 5 days, or in the Freas oven for 2½ days. Moisture determinations made at the end of the drying periods showed that the grain on the ears was reduced to approximately 8 to 9 per cent of moisture in both driers.

After drying, each ear sample was shelled separately and duplicate 100-kernel samples were taken at random and tested for germination by the rag doll method.

The data showing moisture percentages, weights and germination are presented in Table 1.

TABLE 1—COMPARISON BETWEEN SAMPLES OF EAR CORN DRIED IN A FREAS OVEN AND A COMMERCIAL BIN DRIER (Wisconsin type)

Hybrid or variety	Maturity group	Weight of 10-ear sample		Weight of grain (dried)	Weight of cob (dried)	Moisture in ears ①	Moisture in grain (dried)	Germination	
		Original	Dried					Strong	Weak
		lbs.	lbs.	lbs.	lbs.	%	%	%	%
				Bin-dried samples (dried 5 days, 105-110° F.)					
Canada 531	Early	7.0	5.3	4.6	.7	32.3	8.0	99	1
" 606	Medium	6.3	4.7	4.1	.6	34.4	8.2	96	3
" 645	"	8.0	6.0	5.2	.8	33.3	8.2	99	1
" 696	Late	8.0	5.5	4.8	.7	39.0	7.7	98	2
Indiana 610	Very late	9.7	6.5	5.6	.9	40.9	7.9	98	2
Minn. No. 13	Very early	4.8	3.8	3.3	.5	28.6	7.8	96	4
Silver King	Late	7.7	5.6	5.0	.6	35.4	8.1	98	2
Canada Golden Glow	Late	7.9	5.8	5.1	.8	34.8	8.2	97	2
				Oven-dried samples (dried 2½ days, 108°F.)					
Canada 531		6.2	4.8	4.2	.6	31.2	8.6	99	1
" 606		7.6	5.6	4.9	.7	35.0	8.7	96	4
" 645		8.6	6.4	5.6	.8	35.0	8.8	99	1
" 696		8.2	5.7	4.9	.8	39.7	9.2	97	3
Indiana 610		10.1	6.5	5.6	.9	44.2	9.1	96	3
Minn. No. 13		5.0	4.0	3.4	.6	28.4	8.4	95	4
Silver King		8.0	5.8	5.0	.8	36.3	8.8	99	1
Canada Golden Glow		8.1	5.9	5.0	.8	36.2	9.0	98	2

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① Moisture in ears obtained by calculation (difference between original and dried weight of ears + moisture in grain.)

The data show clearly that the drying of the ears by the two methods gave results which were highly comparable. Although the samples varied in moisture content from 28 to slightly over 40 per cent at harvest, the germination obtained in all samples by the use of both driers was essentially the same. It was assumed, therefore, that results comparable with those reported in these investigations, in which drying was done in a Freas oven, could be expected by the drying of similar corn in a commercial bin drier.

As the usual practice in commercial drying is to reduce the moisture content to at least 14 per cent, it was found by previous tests that 48 hours of drying in the Freas oven would reduce the moisture in all ear samples to that level, or slightly below it. Later in this paper it is shown that corn containing 25.2, 35.1 and 44.6

per cent of moisture at harvest, and dried in the Freas oven at 108°F. for 32 days to a uniform moisture content of approximately 2 per cent, suffered little or no injury to the percentage germination as the result of dessication.

Kernel Appearance

Quality in seed corn is often based upon its general appearance. If the kernels are bright and plump, and of typical shape and colour for the particular variety, then it is considered to be good seed, whereas if the kernels are dull, opaque, and somewhat shrunken, it is usually judged to be not so good, even though the percentage germination in both may be approximately the same.

As it is of importance to recognize some of the general effects of maturity and drying upon seed corn, a description of the kernels harvested at different moisture levels and either air dried or artificially dried is given in Table 2.

Kiesselbach(19) states that fully matured seed corn of reasonably low moisture content may be artificially dried at 107° to 112°F. without unfavourably affecting the appearance of the seed in colour, lustre and wrinkling of the pericarp. According to Trost(28) starchiness is characteristic of chaffy, immature ears, while Dungan(8) reports that immature corn contains a higher percentage of soft starch than mature corn. Leonard(22) and Robertson(24) both indicate that bushel weight may be taken as an index of the maturity and quality of seed corn.

According to the seed characteristics described in Table 2 there was very little difference in the appearance of kernels which contained 27 and 32 per cent of moisture, irrespective of the method of drying. At 32 per cent moisture the artificially-dried kernels showed a slight dulling of the pericarp and some wrinkling over the germ.

As the moisture increased to 42, 48 and 58 per cent, the effects upon the appearance became more and more marked both in the air-dried and artificially-dried kernels, and the general result was that they became increasingly unattractive. This applied more particularly to the artificially-dried kernels. There was a loss of brightness and lustre and the kernels appeared dull and opaque; the pericarp tended to lift and blister; the germ became smaller and wrinkled; chaff adhered to more and more kernel tips, and at the higher moisture levels of 48 and 58 per cent the kernels had a decidedly bleached appearance.

Kernel Weight, Volume and Specific Gravity

It seems obvious that the maturity of the corn at harvest should have a definite effect upon the physical characteristics of the individual kernels. Koehler, Dungan and Burlison(20) found that kernel weight, and the specific gravity of the grain increased as the stage of maturity of the harvested seed advanced from the milk to the mature stage. Robinson(25) presented data to show that the kernel weight volume and specific gravity increased as the kernels became more mature.

The data presented in Table 3 show comparisons of weight, volume and specific gavity of kernels harvested with different moisture contents and either air dried or artificially dried. The results represent averages obtained from using triplicate 100 kernel samples. Specific gravity was obtained by using the method according to Wolfe(31);

$$\text{Specific gravity} = \frac{\text{weight of kernels in gms.}}{\text{water displaced in ccs.}}$$

There was a continuous reduction in the kernel weight, volume and specific gravity as the percentage of moisture in the kernels increased, although there were no very marked differences up to 42 per cent. Artificial drying brought about no

TABLE 2—EFFECT OF MATURITY AND ARTIFICIAL DRYING UPON KERNEL APPEARANCE

Moisture in kernels at harvest

Seed character	27%		32%		42%		48%		58%	
	Air dried	Dried 108°F.	Air dried	Dried 108°F.	Air dried	Dried 108°F.	Air dried	Dried 108°F.	Air dried	Dried 108°F.
Pericarp lustre	bright	bright	bright	slightly dull	fairly bright	dull	dull	very dull	very dull	very dull
Pericarp adherence	tight	tight	tight	tight	tight	some blistering on back, sides & germ	some blistering over germ	some blistering over entire kernel	blistering over germ	blistering over entire kernel
Plumpness	plump	plump	plump	plump	less plump	less plump	shrunken	shrunken	badly shrunken	badly shrunken
Horny starch (%)(1)	high	high	high	high	medium	medium	low	low	very low	very low
Soft starch (%)(1)	low	low	low	low	medium	medium	high	high	very high	very high
Germ	large, smooth, bright	large, smooth, bright	large, smooth, bright	large, slightly wrinkled	smaller, slightly wrinkled	smaller, slightly wrinkled	shrunken, dull	shrunken, dull	small, shrunken, very dull	small, shrunken, very dull
Dent	shallow, smooth	shallow, smooth	shallow, smooth	shallow, smooth	shallow, slightly wrinkled	shallow, slightly wrinkled	fairly deep wrinkled	fairly deep wrinkled	badly wrinkled	badly wrinkled
Chaff adherence	10-20% kernels	10-20% kernels	10-25% kernels	10-25% kernels	70-80% kernels	70-80% kernels	80-90% kernels	80-90% kernels	90-95% kernels	90-95% kernels
Color	deep yellow	deep yellow	deep yellow	deep yellow	yellow	yellow	light yellow	light yellow (bleached)	light yellow	light yellow (bleached)

(1) Indicates relation between the proportion of horny and soft starch in the endosperm.

TABLE 3—EFFECT OF MATURITY OF SEED AND ARTIFICIAL DRYING UPON INDIVIDUAL KERNEL WEIGHT, VOLUME AND SPECIFIC GRAVITY

Moisture in kernels at harvest	Air dried			Artificially dried 108°F.		
	Weight	Volume	Sp. gr.	Weight	Volume	Sp. gr.
%	gm.	cc.		gm.	cc.	
27	.301	.244	1.23	.303	.245	1.24
32	.296	.241	1.23	.294	.240	1.23
42	.275	.230	1.20	.277	.232	1.19
48	.238	.199	1.19	.229	.196	1.17
58	.165	.153	1.08	.158	.146	1.08

appreciable changes with respect to any of these characters in comparison with air drying, except for a slight shrinkage in the weight and volume of those kernels harvested at the 48 and 58 per cent moisture levels. As compared with the weights of the kernels containing 27 per cent of moisture at harvest, the kernel weights at the other moisture levels showed the following percentage relationships:

Kernel moisture at harvest %	Air dried %	Artificially dried %
27	100.0	100.0
32	98.3	97.0
42	91.3	91.4
48	79.1	75.6
58	54.8	52.1

Imbibition of Water

Several investigators have studied the relationship between water absorption and kernel maturity. Tascher and Dungan(27) found that immature corn absorbed water more rapidly than mature corn, while Dungan (8)reports that corn containing a high proportion of soft starch in the endosperm, imbibed water at a more rapid rate than corn containing a lesser proportion of soft starch. Robinson(25) found a positive relation between immaturity and rapidity of water absorption, although the actual quantity of water absorbed by each kernel of the samples differing in maturity varied little. He suggests that the greater attraction of a given unit of immature kernel for water might be greater porosity of the pericarp or the higher proportion of soft starch accompanied by a larger percentage of intergranular space. Sprague(26) determined the amount of moisture necessary for germination in corn and found that the moisture content required for germination was approximately 35 and 60 per cent for whole grain and embryo respectively. According to Wolfe(31) small kernels of corn absorbed water more rapidly than large kernels.

In this study duplicate 100-kernel samples taken at random from ears which upon test gave 90 to 100 per cent germination, and representing each of the five stages of maturity, were placed between heavy blotting paper in germinator pans with tight-fitting lids. The blotting paper was kept thoroughly moistened by the addition of water at regular intervals. The pans were placed in a room at approximately 70°F. Initial weights of the kernel samples were recorded and further weights were taken at the end of each 12-hour period before sprouting began. Immediately before each weighing the seed was removed from the pans and the superficial moisture removed by momentary drying between cloths. The results obtained are presented in Table 4.

TABLE 4—EFFECT OF MATURITY OF SEED AND ARTIFICIAL DRYING UPON IMBIBITION OF WATER

Method of Drying	Initial weight per 100 kernels	Increase in weight of 100 kernels during 3 successive 12-hour periods					
		Actual gain			Relative gain		
		1st	2nd	3rd	1st	2nd	3rd
	gm.	gm.	gm.	gm.	%	%	%
		27% moisture in kernels at harvest					
Air dried	30.4	5.7	8.7	11.2	18.8	28.6	36.8
Artificially dried, 108°F	30.8	5.5	8.4	11.1	17.8	27.3	36.0
		32% moisture in kernels at harvest					
Air dried	28.4	5.8	8.3	10.4	20.4	29.2	36.6
Artificially dried, 108°F	28.3	5.2	8.1	10.4	18.4	28.6	36.7
		42% moisture in kernels at harvest					
Air dried	25.8	5.6	8.4	10.4	21.7	32.6	40.3
Artificially dried, 108°F	26.0	5.8	8.6	11.2	22.3	33.1	43.1
		48% moisture in kernels at harvest					
Air dried	22.8	5.1	7.9	10.0	22.4	34.7	43.9
Artificially dried, 108°F	21.9	5.9	8.8	11.7	26.9	40.2	53.4
		58% moisture in kernels at harvest					
Air dried	16.0	4.1	5.8	7.1	25.6	36.3	44.4
Artificially dried, 108°F	15.2	4.8	6.8	9.2	31.6	44.7	60.5

The data in Table 4 show that in the air-dried samples the actual amount of water taken up increased at each weighing and was successively higher with each advance in the stage towards greater maturity, imbibition being lowest in the immature kernels and highest in the well-matured kernels. While the artificially-dried samples did not show quite the same consistency of results, nevertheless the lowest weight of water imbibed was by the most immature sample.

As the original weight of the kernel samples increased with each advance towards better maturity, the weight of the water imbibed was related to the initial kernel weight and placed on a percentage basis. By doing this it was found that the percentage imbibition increased directly with immaturity and that this increase was most marked in the artificially-dried samples which originally contained 48 and 58 per cent of moisture.

Comparison between the air-dried and artificially-dried samples showed very little difference in moisture imbibition in the 27, 32 and 42 per cent moisture samples, but the artificially-dried 48 to 58 per cent moisture samples showed a much increased imbibition both in actual amount and percentage as compared with the corresponding air-dried samples. Imbibition was most rapid in the first 12-hour period, but diminished in each succeeding period except in the artificially-dried, 58 per cent moisture sample, in which the water absorbed was greater in the third than in the second 12-hour period.

Sprouting of Plumule and Radicle, and the Development of Secondary Roots

After having determined the effects of maturity and artificial drying upon the imbibition of water it was logical to proceed with the study of germination and seedling development. Koehler, Dungan and Burlison(20) found that the most vigorous seedlings were produced by mature seed, and observed that the vigour of the seedlings had a direct bearing upon the field stand. Observations made by Robinson(25) after kernels had been in the germinator 34 hours, revealed that the immature kernels started germinating more rapidly than those more fully developed. He attributed quicker germination to more rapid water absorption, more sugar in the immature kernels and greater diastatic activity. He also found that while the immature kernels had the greater root and plumule development at the end of three days, the mature kernels equalized the weights by the fourth day and both radicles and plumules exceeded those of the immature kernels by the fifth day. Duncan and Marston(7) concluded that the earlier the stage of kernel maturity and the higher the drying temperature the greater the loss in germination. Kiesselbach(18) found that ears harvested at weekly intervals, from the late milk to mature stage, germinated 94 to 98 per cent when air dried. The same author(19) dried seed corn testing 19, 27, 30, 50 and 57 per cent moisture at a temperature of 112°F. No damage occurred to the percentage and vigour of germination of seed containing 19, 27 and 30 per cent moisture, but that which contained 50 and 57 per cent moisture fell off in 5 days to 90.5 and 83 per cent germination respectively, and the vigour of the sprouts was greatly reduced. Dried at 107°F. both the vigour of the sprouts and the percentage germination were materially reduced in corn containing 55 per cent moisture. Alberts(2) found that immature seed gave lower percentage germination and produced weaker sprouts than mature seed. Dungan(8) reports that mature corn germinated somewhat slower but the seedlings were more vigorous and had more secondary roots and longer shoots than immature corn. Working with clover seeds Afanasjev(1) found that artificial drying at 50°C. for 15 hours increased germinability by 3.4 per cent, but reduced the energy of sprouting by 3.3 per cent as compared with natural drying.

Kernels from the same high-germinating ears used for the moisture imbibition studies were used for observations on sprouting. Duplicate 100-kernel samples from the air-dried and artificially-dried ears were placed between thoroughly moistened heavy blotting paper in germinator pans which were kept in a room at approximately 70°F. The blotting paper was kept moistened with regular additions of water. Observations on the development of sprouting were begun on the third day and continued at 12-hour intervals until the seventh day. The results of the observations are recorded in Table 5.

According to the data in Table 5, the sprouting of radicles was speeded up, in the beginning, in all of the artificially-dried as compared with the air-dried samples. Radicles appeared most rapidly in the most immature samples, 48 and 58 per cent moisture at harvest. Illustration of this is shown in Fig. 2. The artificially-dried kernels, 48 and 58 per cent moisture, produced the highest number of radicles at the first count. These were the two samples which had the highest percentage water imbibition in the imbibition test. Twelve hours after the first observations were made the more mature samples had evened up the count and from then until the final observations were completed radicles appeared in all samples, both air-dried and artificially-dried, at about the same rate.

Plumules, unlike the radicles, developed most rapidly in the more mature, low-moisture kernels. The most immature artificially-dried sample had the lowest count throughout, and at the end of the sixth day had averaged only 63 plumules per 100 kernels, as compared with from 95 to 100 plumules in each of the 27, 32 and 42 per cent moisture samples. Only those plumules were counted as sprouted which succeeded in breaking through the pericarp. In the immature 48 to 58 per

TABLE 5—EFFECT OF MATURITY OF SEED AND ARTIFICIAL DRYING UPON SPROUTING OF THE PLUMULES AND RADICLES, AND THE DEVELOPMENT OF SECONDARY ROOTS

Days after planting	Moisture in kernels at harvest									
	Air-dried					Artificially-dried 108° F				
	27%	32%	42%	48%	58%	27%	32%	42%	48%	58%
	Percentage of kernels which developed sprouts									
3rd day										
9 a.m.										
plumules	0	0	0	0	0	0	0	0	0	0
radicles	20	24	22	30	47	26	24	30	68	86
secondaries	0	0	0	0	0	0	0	0	0	0
9 p.m.										
plumules	21	19	8	5	4	28	18	7	8	7
radicles	84	77	89	74	79	89	94	97	84	96
secondaries	0	0	0	0	0	0	0	0	0	0
4th day										
9 a.m.										
plumules	66	71	57	22	22	81	68	54	51	30
radicles	98	91	100	99	88	98	100	95	97	97
secondaries	20	16	11	3	1	32	24	3	0	0
9 p.m.										
plumules	88	85	90	67	45	96	93	87	82	43
radicles	99	93	100	100	91	98	100	97	98	98
secondaries	69	68	62	46	23	83	84	53	36	2
5th day										
9 a.m.										
plumules	95	92	96	84	66	98	96	93	87	53
radicles	99	98	100	100	94	99	100	97	98	98
secondaries	88	85	90	65	53	94	91	73	53	13
6th day										
9 a.m.										
plumules	98	97	100	93	83	99	100	96	89	63
radicles	99	99	100	100	97	99	100	97	98	98
secondaries	97	95	98	92	75	99	99	90	74	32

cent moisture samples particularly, many plumules were unable to penetrate the pericarp, either through lack of vigour or possibly as the result of loosened pericarps, which permitted the plumule to develop within them. As Weatherwax(32) states, such seeds may have been near the end of the term of viability. Plumules of the more mature samples penetrated the pericarps readily and almost without exception.

Immaturity also had a decided effect in retarding the development of secondary or lateral roots, which again was most marked in the artificially-dried, immature samples. At the end of the sixth day in the artificially-dried 58 per cent moisture sample, only 32 per cent of the kernels had produced secondary roots as compared with 99 per cent in the two mature samples. In the mature samples artificial drying had the effect of speeding up the development of secondary roots as compared with air drying, although at the final reading on the sixth day the total counts were approximately the same in thsee samples.

Fig. 3 shows four of the germinator pans, 50 kernels in each, photographed following the final observations on the sixth day. They illustrate the vigorous

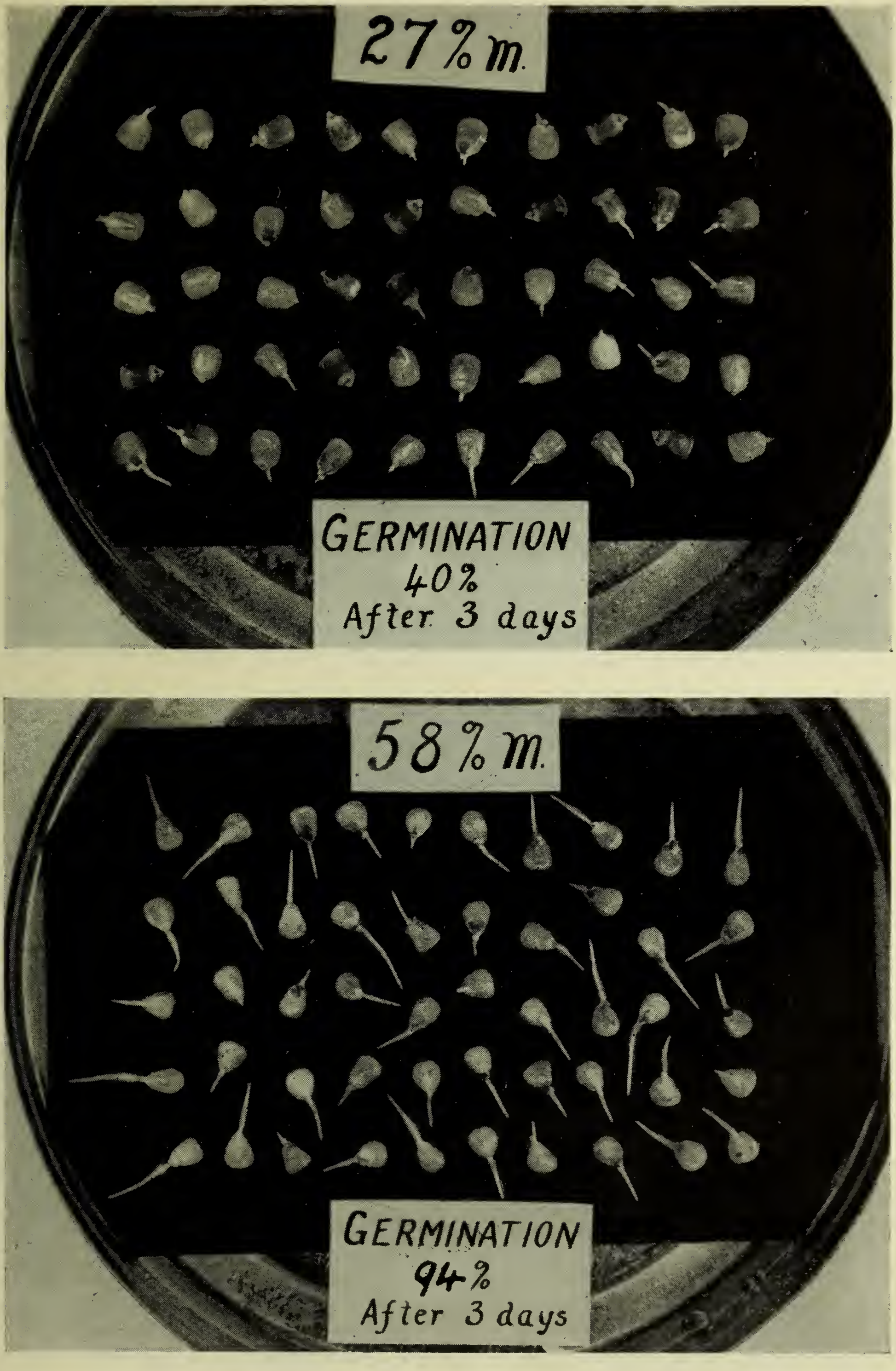


Fig. 2. Radicle development after 3 days in kernels containing 27 per cent and 58 per cent of moisture at harvest, and artificially dried.

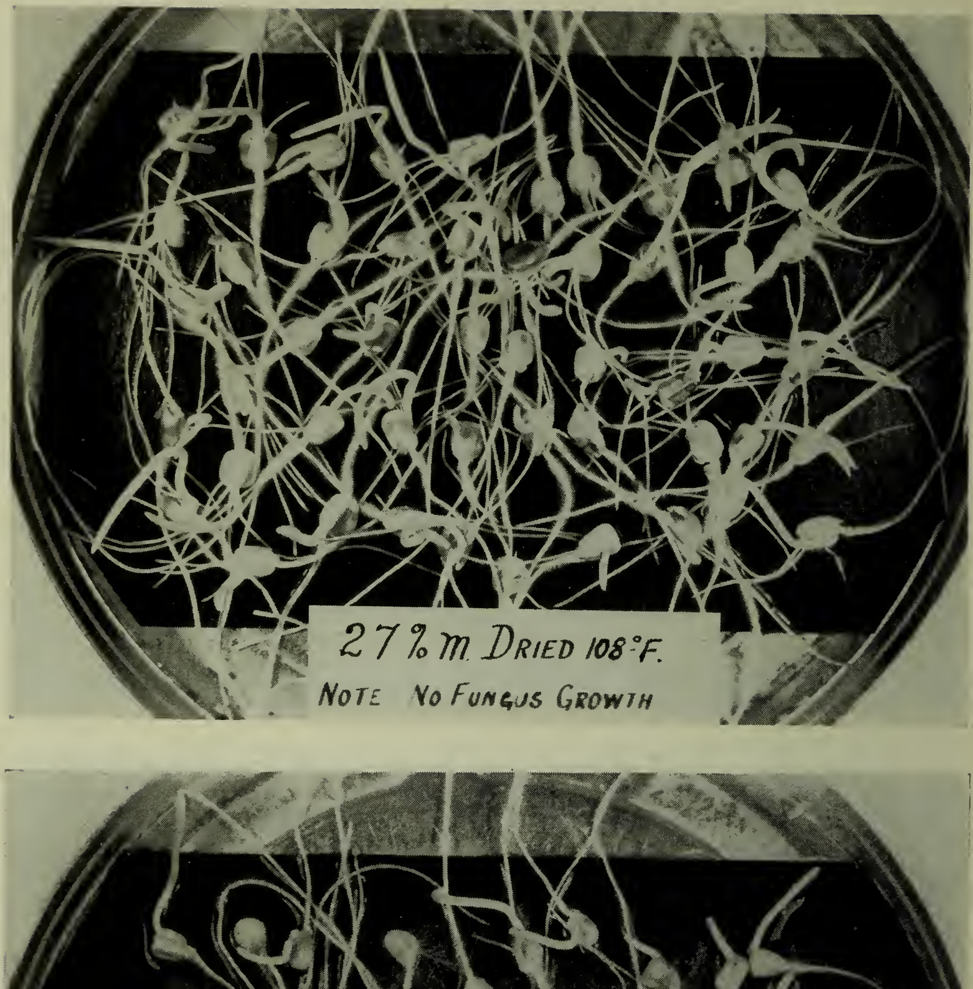


Fig. 3. Germinator pans showing seedlings grown from kernels containing 27 and 58 per cent moisture at harvest, air dried and artificially-dried.

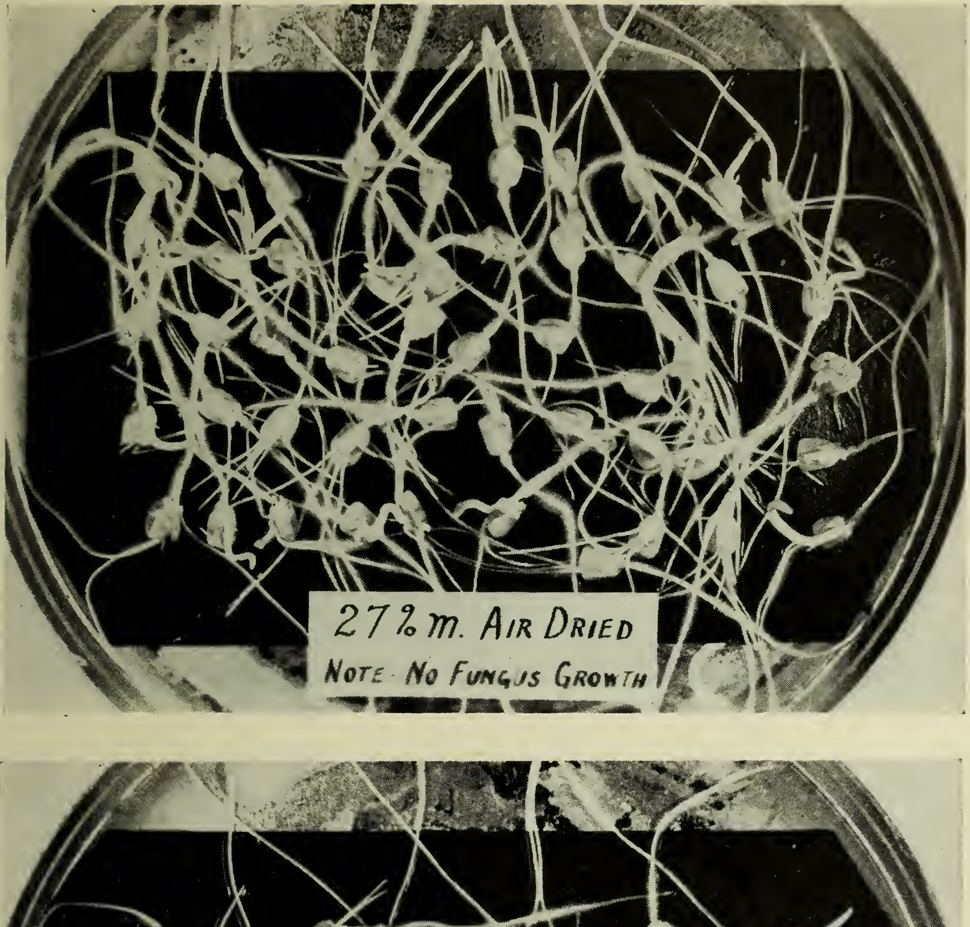


Fig. 3. Germinator pans showing seedlings grown from kernels containing 27 and 58 per cent moisture at harvest, air dried and artificially dried.

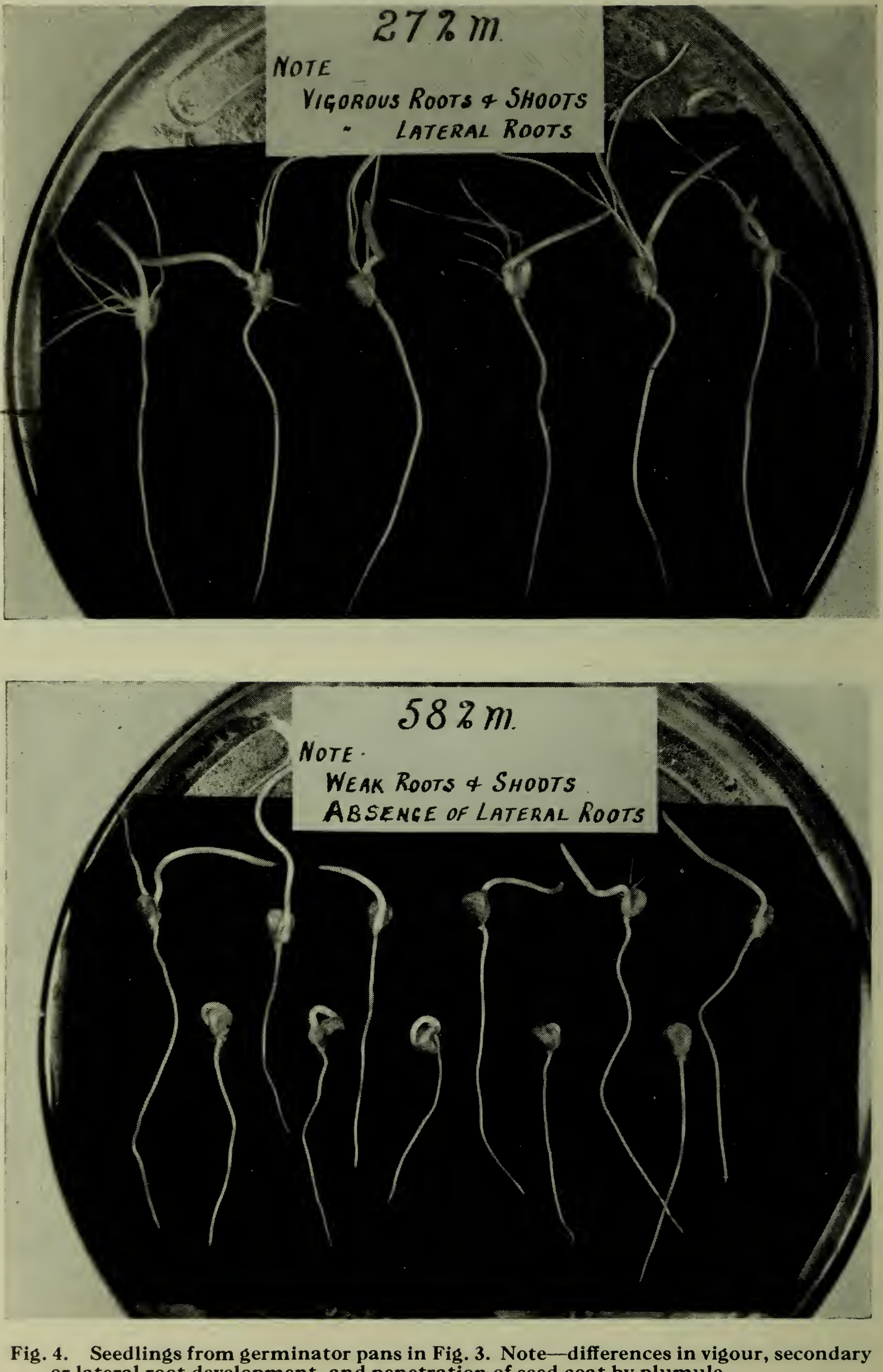


Fig. 4. Seedlings from germinator pans in Fig. 3. Note—differences in vigour, secondary or lateral root development, and penetration of seed coat by plumule.

character of the seedlings from well-matured kernels as contrasted with the less vigorous and more spindly nature of the seedlings from the immature kernels. Obvious also is the lack of secondary roots in the immature samples and the inability of many plumules to penetrate the pericarp. (See also Fig. 4). The artificially-dried immature samples, Fig. 3, show the presence of considerable fungus growth identified as rhizopus spp., which is responsible for scutellum rot, and also fusarium spp. These appeared to have been encouraged by the artificial heat treatment. The reason for this is not entirely clear. It might be that a sudden check of the metabolic and maturation processes within the seed, caused by rapid drying and consequent drop in the respiration rate, resulted in maintaining a relatively high sugar content in the dried kernels of this highly immature sample. The high sugar content would provide a very favourable medium for mycelial growth and by greater distention of the cell walls as the result of increased osmotic pressure, would render them easier for the mycelium to penetrate.

As an indication of the more vigorous seedling growth produced by the matured kernels, the plumules, radicles and lateral roots were separated from 50 kernels of each air-dried sample on the sixth day. These were reduced in an oven to absolute dry weight, and weighed both with and without the scutellums, and the following results obtained.

Moisture in kernels at harvest	Absolute dry weight of plumules, radicles and secondaries from 50 air-dried kernels	
%	+scutellums gm.	−scutellums gm.
27	3.85	2.18
32	3.66	1.99
42	3.40	1.95
48	2.92	1.83
58	2.15	1.50

As a general observation it may be stated that as the moisture in the kernels increased above the 42 per cent level the seedlings became progressively less vigorous and more spindly, both in the air-dried and artificially-dried samples.

Seedling Emergence

The successful emergence of seedlings from the soil is largely dependent upon the development of strong, vigorous sprouts. Frequently seeds germinate but fail to emerge because of insufficient nourishment resulting from low food reserves, or the food reserves not being made available rapidly enough in the initial stages of growth to supply the necessary energy to enable the young seedlings to push through to the surface of the soil. Kienholz(17) in a study of the effect of heat treatment upon the germination and seedling growth of corn, found that treated seed which produced an average germination of 60 per cent in the rag doll, germinated only 27.8 per cent in the soil. He examined seed planted in the greenhouse and found that while many of the heat treated kernels had developed a short plumule or radicle, they lacked sufficient energy to force their way to the surface of the soil. Robinson(25) observed that seedlings emerged most rapidly from mature seed when grown in greenhouse flats. He also found that a trend existed showing greater plant weight as more mature seed was used. According to Washko(31) the effect of injurious drying temperatures on seed corn was reflected not only in decreased germinating capacity, but in delayed soil emergence, in retarded growth and in field performance. Tascher and Dungan(27) suggested that the superior vigour of seedlings from mature corn may be due primarily to the greater quantity of reserves which the longer period on the parent plant made possible.

TABLE 6—EFFECT OF MATURITY OF SEED AND ARTIFICIAL DRYING UPON THE GERMINATION AND SEEDLING EMERGENCE

Moisture in kernels at harvest	Method of drying	Seedling emergence No. of days after planting												Weight of shoots①		
		6	7	8	9	10	11	12	13	14	15	18	Total	Green	Dry	D.M.②
		%	%	%	%	%	%	%	%	%	%	%	%	gm.	gm.	%
27%	Air dried......	48	96	100									100	49.5	3.47	7.01
"	108°F. 48 hrs...	6	81	82	85	88	89	91	93	96	98		98	31.9	2.29	7.19
32%	Air dried......	18	91	96	98								98	47.8	3.41	7.13
"	108°F. 48 hrs...	6	77	82	86	91	92	94	95	96	98		98	31.0	2.29	7.39
42%	Air dried......	8	78	86	91	97							97	33.6	2.42	7.20
"	108°F. 48 hrs...	4	53	64	80	82	85	86	90	91			91	20.5	1.55	7.56
48%	Air dried......	2	51	74	91	94	96	97					97	28.4	2.10	7.39
"	108°F. 48 hrs...	4	27	29	38	43	46	48	52	53			53	7.0	.55	7.85
58%	Air dried......	2	34	53	66	83	88	92	96				96	19.5	1.55	7.95
"	108°F. 48 hrs...	0	0	6	8	10	13	14	16	16	18		18	.8	.07	8.75

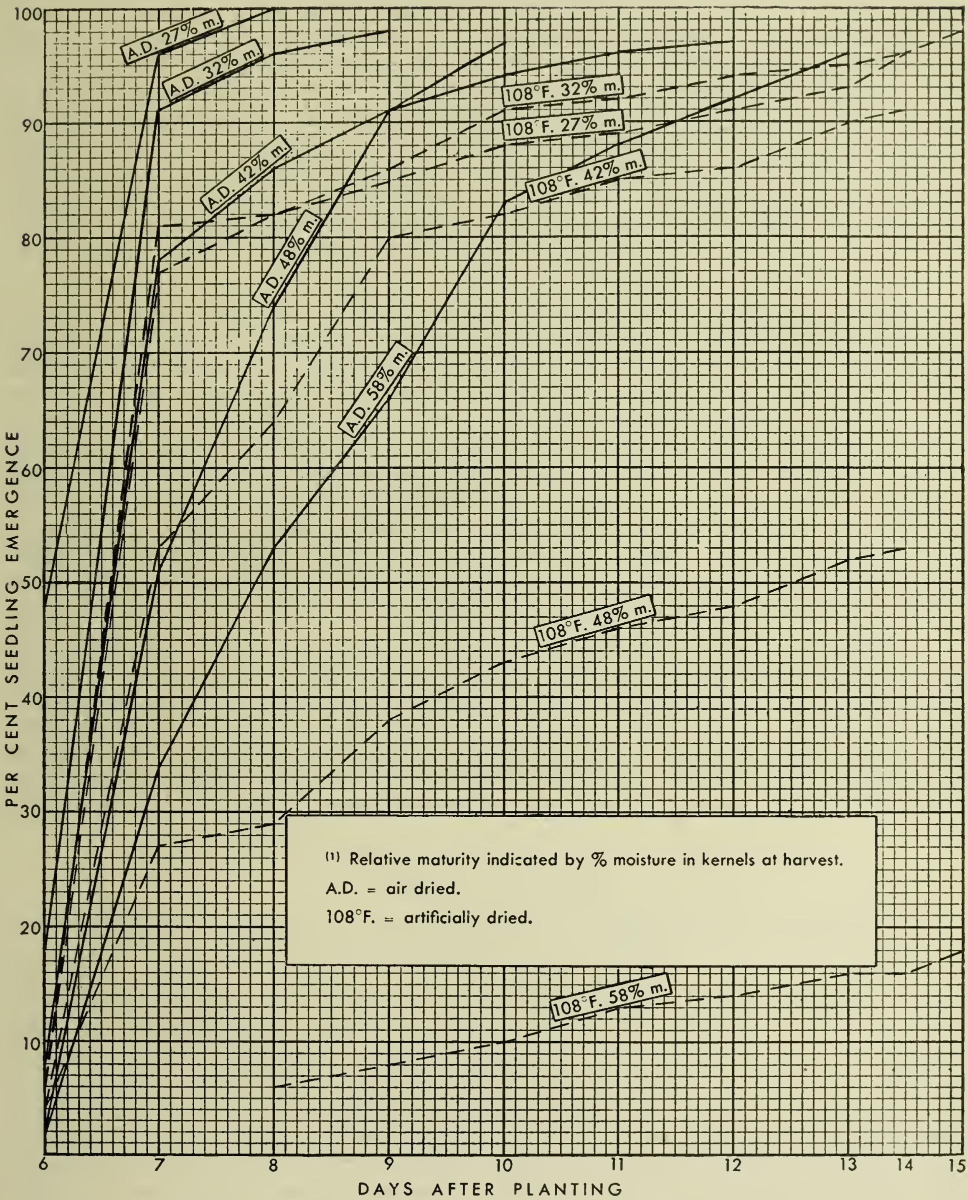
① Shoots = above ground portion.
② Dry matter.

In conducting this study, 100 kernels were taken at random from high germinating air-dried and artificially-dried ears at each of the five stages of maturity. Each 100-kernel sample was divided into two lots of 50 and these were planted in greenhouse flats and covered with an inch of firmly packed soil. The flats were placed in a greenhouse and held at a temperature ranging between 55°F. at night and 85°F. during the day. They were watered regularly and uniformly. The seedlings started to emerge on the sixth day after planting and a daily record of emergence was kept for a period of 12 days thereafter. On the eighteenth day the young corn shoots were carefully cut off at the ground level and weighed green, and then dried to absolute dry weight and weighed again. The percentage emergence and average weights for the duplicate 50-kernel plantings are presented in Table 6. The rate and percentage of seedling emergence are also shown graphically in Fig. 5.

It is interesting to observe from the data in Table 6, that while seedling emergence was high in all of the air-dried material, and had reached over 80 per cent in all samples by the tenth day after planting, immaturity nevertheless resulted in slowing down the rate of emergence. Maturity effects were most notable on the day emergence started, 6 days after planting. By this time the well-matured 27 per cent moisture sample had emerged 48 per cent, while emergence in the remaining four samples amounted to 18, 8, 2, and 2 per cent respectively, as the kernel moisture content increased. Seedling emergence was 100 per cent complete in the well-matured sample 8 days after planting, but only 53 per cent of the most immature sample had emerged at the end of that time. It required 13 days for this sample to complete 96 per cent emergence.

Artificial drying had two very definite effects. It caused a slowing down in the rate of emergence in all samples, and greatly reduced the total seedling emergence of the two most immature samples. In the air-dried 27 per cent and 32 per cent moisture seed it required only 8 and 9 days to complete 100 per cent and 98 per cent seedling emergence respectively, while in the artificially-dried seed at the same moisture levels it required 15 days to complete 98 per cent seedling emergence. It should be noted, however, that both of these had 82 per cent emergence after only 8 days. With respect to the immature samples, while the air-dried kernels at the 48 per cent moisture level produced 97 per cent seedling emergence in 12 days, it required 14 days to produce 53 per cent emergence in the corresponding artificially-dried sample. At the 58 per cent moisture level, the air-dried kernels emerged to the extent of 96 per cent in 13 days, whereas the artificially-dried kernels required 15 days for a total seedling emergence of only 18 per cent. Such a wide

Fig. 5. Illustrating the effects of maturity (¹) of seed and artificial drying upon seedling emergence.



(1) Relative maturity indicated by % moisture in kernels at harvest.
A.D. = air dried.
108°F. = artificially dried.

difference between these two samples suggests that the temperature of drying may have been too high for the immature corn, resulting in either or all of the following: direct injury to the meristematic cells of the embryo; injury to those cells of the scutellum responsible for the secretion of diastase and other enzymes; total or partial destruction of the enzymes themselves or lowering of their activities.

The influence of maturity and of artificial drying upon the time of emergence and resulting seedling growth is clearly revealed by the green and dry weights of the above-ground shoots. In the air-dried samples although the difference in total seedling emergence between the 27 per cent and the 58 per cent moisture samples was only 4 per cent, the difference in the green and dry weights of the young shoots amounted to 153.9 and 123.9 per cent respectively. Such wide differences in weight are explained by the fact that the 27 per cent moisture sample had the same seedling emergence in 7 days as the 58 per cent moisture sample had in 13 days and this early rapid emergence resulted in the production of a uniform growth of much stronger and more vigorous seedlings. In comparison with the artificially-dried material, the corresponding air-dried samples produced greater green and dry weights at all moisture levels. This was probably the result of slightly earlier emergence and somewhat more vigorous and uniform seedling growth at the 27, 32, and 42 per cent moisture levels and to much earlier and much higher total emergence at the 48 and 58 per cent moisture levels.

With respect to the artificially-dried corn there was very little difference between the green and dry weights of above-ground shoots produced by the 27 and 32 per cent moisture samples. This was to be expected in view of the fact that the rate of emergence and total emergence were practically the same in both. In the 42, 48 and 58 per cent moisture samples there was a slowing down in the rate of emergence and a sharp drop in total emergence. The green and dry weights were reduced correspondingly. The 58 per cent moisture sample furnished a splendid example of the results of slow emergence and lack of seedling vigour. Eighteen per cent of the seedlings required 15 days to emerge and the shoots produced a green weight of 0.8 gm. This was in contrast with the 27 and 32 per cent moisture samples in which 98 per cent of the seedlings emerged in the same period of time, 15 days, but which averaged 31.5 gm. in weight.

A rather interesting observation is to be noted in the percentage dry matter produced by the shoots at the different stages of maturity. As shown in Table 6, in both air-dried and artificially-dried samples the percentage dry matter increased with immaturity. Also the artificially-dried samples had slightly higher percentages of dry matter than the corresponding air-dried samples at each of the five moisture levels. A possible explanation of this might be that as the result of slower emergence the younger seedlings may have contained a higher concentration of sugars.

Enzyme Activity

Enzymes play an important role in the germination of seeds. In the corn seed most of the reserve food stored in the endosperm is in the form of starch, and as such is insoluble and unavailable to the embryo. Early in the process of germination the epithelial cells of the scutellum, that are in contact with the endosperm, secrete certain enzymes. The most important of these secretions is probably diastase or amylase. This diffuses into the endosperm and transforms the reserve starch into the sugar, maltose, which being soluble is absorbed by the scutellum and transported to the growing points of the developing embryo where it is utilized. The amount and rate at which the food is received at this stage undoubtedly has a great influence upon the vigour and vitality of the young seedling, and is a factor of great importance in determining whether or not it will emerge successfully from. the soil and develop into a strong, vigorous plant of normal growth and productivity It is obvious then, that any factor which affects the normal secretion or activity of the diastase must inevitably affect also the normal progress of germination and growth. Therefore, because of the importance of diastase in germination, and during the initial stages of seedling development, it seemed advisable to obtain a comparison between the air-dried and artificially-dried samples with respect to the activity of this particular enzyme.

In a study of diastatic activity in germinated and ungerminated air-dried seed corn, Tascher and Dungan(27) found that in the ungerminated seed there was no significant difference between the diastatic activity of horny and floury corn of the same maturity, but observed greater diastatic activity in immature than mature seed. In germinated seed they found that maturity of the seed did not influence diastatic activity to any extent. They reported an increase in the activity of the diastase as germination progressed. Robinson(25) observed that in two years out of three, the diastatic activity for each unit weight and for each individual corn kernel decreased as the kernels matured. In working with barley, Pickler(23) found that at a constant temperature, diastase formation increased with the moisture content of the grains. Brown and Morris(3) reported that in barley the activity of diastase increased with maturity and that the activity also increased as germination progressed. According to Waksman and Davison(29) small grains of barley produced more diastase than large grains.

Three hundred and fifty kernels were taken at random from each of the ear samples which originally contained 27, 32, 42, 48 and 58 per cent of moisture at harvest. These were placed between thoroughly-moistened, heavy blotting papers in germinator pans, and held in a room at approximately 70°F. The blotting paper was kept thoroughly moistened by the addition of water at regular intervals. At the end of each day, for a period of 7 days, 30 ungerminated and 30 germinated kernels of each sample were removed from the pans. Each 30 kernels comprised duplicate 15-kernel samples which were tested separately for diastase and the results of the two determinations were then averaged.

Ungerminated kernels were obtained only during the first three days. It is quite possible that they included a few weak, slowly germinating kernels, in addition to dead kernels. Although the main purpose of this test was to determine the effect of moisture content and drying upon the diastatic activity of the germinating kernels, these ungerminated samples did serve to indicate the rapidity with which the activity of diastase is speeded up in the kernels of normal germination.

No germinated kernels were obtained until after two days in the germinator pans, at which time a good percentage of the kernels had sprouted radicles, averaging ⅛ to ⅓ of an inch in length. The seedlings developed rapidly, until at the end of the sixth day they showed the following average amount of growth in both air-dried and artificially-dried samples:

GROWTH OF SEEDLINGS AFTER 6 DAYS IN GERMINATOR

	Moisture in kernels at harvest				
	27%	32%	42%	48%	58%
	in.	in.	in.	in.	in.
Plumules	1¼–1¾	1¼–1¾	1¼–1¾	1½–2	1½–2
Radicles	3–4	3–4	3–4½	3–4½	3–4½

The growth of both the plumules and the radicles was much more spindly in the immature than in the more mature samples. A much higher percentage of the kernels in the mature samples developed secondary roots than in the immature samples, likewise the number of secondaries per kernel increased with advancing maturity. In the immature kernels with secondaries present, they rarely numbered more than 1 to 3, whereas in the mature kernels they usually numbered 2 to 5. While the reason for this difference is not entirely clear it is quite possible that the immature ears were harvested before the buds giving rise to the secondary roots were laid down.

In testing for diastase the Hawk and Bergeim method was used, with some slight modifications. The starch, iodine and sodium chloride solutions were prepared as outlined in the method, and buffered with sodium acetate to pH 4.4.

By spacing the time at which the samples were started in the germinators it was possible to test each one for diastase precisely at the end of each 24-hour period.

At the time of testing, each 15-kernel sample was carefully washed with distilled water and thoroughly ground in a mortar. A little fine sterilized sand was added to aid in the grinding. The dry seed samples were ground in a C & N laboratory hammer mill made by Gallenkamp & Co., London, England. The ground kernels were washed into an Erlenmeyer flask with 50 cc. of distilled water and the flask was placed in a constant temperature water bath at 38°C. for 30 minutes, with occasional shaking. At the end of 30 minutes the flask was removed, thoroughly shaken and the contents filtered·

A test tube was placed in a beaker of water maintained at 38°C., and into the test tube was measured the following:—

5 cc. Starch solution
2 cc. NaCl (1%)
2 cc. Buffer solution

Noting the time, 2 cc. of the filtrate (enzyme solution) was added to the test tube and stirred. At regular intervals, by means of a pipette, two drops of the mixture in the test tube were added to a definite quantity of iodine solution already placed in a spot plate. The time required to reach the achromic point* was recorded.

Some difficulty was encountered in recording accurately the time of the achromic point in those samples in which the diastase was very low in activity, for example the dry seed samples. The approach to the achromic point was so gradual and so slow that it was very difficult to determine the exact line at which the end point was reached. The times were recorded as accurately as possible.

In Table 7 are shown the results obtained in the diastase tests.

It is interesting to note that in the dry seed samples, while the diastatic activity was very low it showed a definite increase with immaturity, and was somewhat greater in the air-dried than in the artificially-dried kernels. This same relationship held true with respect to these samples after they had absorbed moisture in the germinator pans for one, two and three days, although still 'ungerminated'. At the end of the third day the artificially-dried 'ungerminated' kernels at the 27 and 32 per cent moisture levels showed a tremendous speeding up of the diastase activity compared with the more immature samples, but they still lagged behind the comparable air-dried samples.

Diastase activity showed a great increase in the germinated seeds at the end of the second day in comparison with that of the original dry seed samples. While it was greatest in the air-dried kernels at all moisture levels, it had progressed to a very uniform rate in both air-dried and artificially-dried samples. Progressively increased activity was shown in all germinated samples at the end of the fourth and fifth days, but by the end of the sixth day the rate of activity appeared to have reached its highest level. The time required to reach the achromic point was approximately the same for all air-dried samples, and also for all artificially-dried samples, but the latter needed almost twice the amount of time to reach the achromic point as the air-dried samples at all moisture levels. There was some tendency for the most immature kernels, 58 per cent moisture, to show the lowest activity in both the air-dried and artificially-dried samples continuously after the second day.

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*The point at which no colour develops with the addition of the mixture to iodine.

TABLE 7—EFFECT OF MATURITY OF SEED AND ARTIFICIAL DRYING UPON DIASTASE ACTIVITY AS INDICATED BY THE NUMBER OF MINUTES REQUIRED TO REACH THE ACHROMIC POINT

Seed treatment	Moisture in kernels at harvest									
	27%		32%		42%		48%		58%	
	Air dried	108° F.	Air dried	108° F	Air dried	108° F.	Air dried	108° F.	Air dried	108° F.
	min.	min.	min.	min.	min.	min.	min.	min.	min.	min.
Dry seed.......	*	*	*	*	†	*	270	*	110	†
Soaked seed....										
1 day Ungerminated..	*	*	*	*	185	*	220	*	105	‡
2 days Germinated.....	14	21	15	20½	14	19½	12	21	13	24½
Ungerminated..	33	204	38	169	25	118	23	230	15	190
3 days Germinated.....	2½	6	3½	5	3	4	3	5½	5	7
Ungerminated..	11½	18	5	9½	3½	47	3	51	4½	110
4 days Germinated.....	1½	3	1½	3	2	3	1½	2¾	3½	4
5 days Germinated.....	1¼	2¼	1	2½	1−	2	1−	2½	2	2¼
6 days Germinated.....	1¼−	1¾	1−	1½	1−	1½	1−	1¾	1+	2½
7 days Germinated.....						1½	1−	1	1+	

*No apparent activity after observing 24 hours.
†Trace of activity after 12 hours.
‡ " " " 10 hours.

Kernel Structure and Composition

The degree of maturity, as indicated by kernel moisture content at harvest, has been shown to have had a marked effect upon kernel weight, volume and specific gravity. It also greatly affected kernel appearances, the more immature the corn the more marked the opacity of the kernels, and the smaller the germs. It became of interest, therefore, to determine also the effects of maturity upon kernel structure and composition.

In a three-year test Robinson(25) found that the percentage of germ was slightly less for the immature kernel samples, although the differences were not significant. Dungan(8) reported that immature corn has a higher percentage of soft starch than mature corn, while Trost(28) observed that starchiness is characteristic of chaffy, immature ears, but is not necessarily associated with normally matured ears of rough indentation. Using the variety Silver King, Wolfe(31) found that small and large kernels from the same ear possessed about the same relative proportions of the different parts, including outer skin, tip-cap, soft starch and horny starch, and that there were no pronounced differences in their chemical composition. Hopkins(14) made a mechanical analysis of kernels from selected ears of corn and obtained the following average percentages of the different parts, tip-caps—1.43; hulls—5.83; horny part—54.19; white starch—27.54; germs—11.02.

In the present investigation 100 kernels taken from air-dried and artificially-dried ears harvested at each of the five moisture levels were separated by hand into the constituent parts, including tip-cap, pericarp, germ, soft and horny portions of the endosperm. Each 100 kernels were divided into 10 lots of 10 kernels each, and these were dissected and weighed as unit samples. To aid in the separation the kernels were first placed in lukewarm water and allowed to remain there for 20 to 25 minutes. Following this they were removed and dissected with a sharp knife. The kernel parts were exposed at room temperature for about 24 hours and then weighed.

Separations of the tip-cap, pericarp, and germ were quite easily accomplished. Separation of the soft and horny endosperm was much more difficult, and while no claim is made for perfect separation, the task was performed as carefully as possible, and the results obtained were believed to be reasonably accurate. No attempt was made to isolate the horny gluten which forms a thin layer of tissue surrounding the endosperm immediately beneath the pericarp, and which, according to Hopkins(14), comprises on the average about 5 to 7 per cent of the entire kernel. It was included with the endosperm.

TABLE 8—EFFECT OF MATURITY OF SEED AND ARTIFICIAL DRYING UPON THE WEIGHT(1) AND PERCENTAGE OF CONSTITUENT PARTS OF CORN KERNELS

Kernel part	Moisture in kernels at harvest				
	27%	32%	42%	48%	58%
			Air-dried		
Tip cap.....gm.	.38	.42	.40	.40	.32
Pericarp.....gm.	1.62	1.60	1.42	1.34	1.16
Germ.....gm.	3.90	3.64	3.08	2.56	1.34
Endosperm					
Soft portion.....gm.	10.06	10.70	10.98	11.04	7.72
Horny portion.....gm.	14.20	13.76	10.34	6.88	4.60
	30.16	30.12	26.22	22.22	15.14
Tip cap.....%	1.27	1.39	1.53	1.80	2.11
Pericarp.....%	5.39	5.32	5.42	6.03	7.66
Germ.....%	12.92	12.09	11.75	11.52	8.85
Endosperm					
Soft portion.....%	33.36	35.52	41.87	49.68	51.00
Horny portion.....%	47.05	45.68	39.43	30.97	30.38
			Artificially-dried		
Tip cap.....gm.	.38	.38	.36	.36	.32
Pericarp.....gm.	1.46	1.48	1.16	1.28	1.18
Germ.....gm.	3.06	3.14	2.60	2.12	1.12
Endosperm					
Soft portion.....gm.	8.94	9.32	10.36	10.42	7.66
Horny portion.....gm.	14.40	13.82	9.98	6.18	3.70
	28.24	28.14	24.46	20.36	13.98
Tip cap.....%	1.35	1.35	1.47	1.77	2.29
Pericarp.....%	5.17	5.26	4.75	6.29	8.44
Germ.....%	10.84	11.16	10.63	10.42	8.01
Endosperm					
Soft portion.....%	31.66	33.12	42.35	51.17	54.79
Horny portion.....%	50.98	49.11	40.80	30.35	26.47

(1)100 kernels (approx. moisture content, 9%)

In Table 8 the weights of the separated portions of the 100 air-dried and artificially-dried kernels and their percentages are shown. It is evident from the data that no marked changes resulted from artificial drying.

With respect to the weight of the kernel parts, the tip-caps did not show any very wide variations, although the 58 per cent moisture samples was the lowest. Pericarp weight increased gradually with maturity. Germs showed a definite change in weight with each stage of maturity, being highest in the well-matured, and lowest in the milk or immature. Germ weight of the matured kernels was almost three times the weight of the germs from the immature kernels. The weight of the soft portion of the endosperm increased with each stage towards greater immaturity up to 48 per cent moisture. It was actually lowest in the 58 per cent moisture sample because of the low total weight of the kernels at this maturity stage. Weight of horny endosperm was highest in the most mature and lowest in the most immature samples. Total kernel weights decreased sharply with immaturity, that of the 27 per cent moisture level being almost twice that of the 58 per cent moisture level.

Percentages of the different parts, based upon the kernel weights, showed a progressive increase in the percentage of tip-caps and pericarps with each stage towards immaturity, this increase being most marked at the 48 and 58 per cent moisture levels. While the weight of tip-caps in the most immature kernels was only slightly less than those of the well-matured kernels, the percentage of the kernel weight was almost twice that of the well-matured samples. The percentage of germ was highest in the well-matured kernels and decreased slightly with immaturity, with a sharp drop in the percentage in the most immature or milk stage kernels. Germ percentage was 12.92 in the well-matured and only 8.85 in the milk stage or 58 per cent moisture air-dried kernels. The soft portion of the endosperm increased sharply in percentage with immaturity, while the horny portion decreased as sharply in the same direction.

Thus it is seen that the two mature samples had the lowest percentages of tip-caps; the highest weight but lowest percentages of pericarps; and of the more useful parts of the kernel, the highest weights and percentages of germ, the lowest weights and percentages of soft endosperm and the highest weights and percentages of horny endosperm. In these two samples the tip-caps and pericarps averaged 6.68 per cent of the total kernel weight, while in the immature, 48 and 58 per cent moisture samples they amounted to 7.83 per cent and 9.76 per cent respectively.

With respect to the endosperm, which is the largest and most important part of the corn kernel, there is an interesting comparison to be made between its weight and its percentage at the different stages of maturity. This relationship is shown in Table 9.

TABLE 9—COMPARISON OF THE WEIGHT AND PERCENTAGE OF THE ENDOSPERM OF CORN KERNELS OF DIFFERENT MATURITIES(1)

Kernel part	Moisture in kernels at harvest (%)				
	27	32	42	48	58
Endosperm (100 kernels)................gm.	24.26	24.26	21.32	17.92	12.32
Endosperm (100 kernels)..................%	80.4	81.2	81.3	80.7	81.4

(1)Difference in maturity indicated by percentage of moisture at harvest.

The table shows that while the amount of endosperm decreased steadily with immaturity and was almost twice as much by weight in the matured as in the most immature kernels, its percentage in relation to kernel weight was approximately the same at all stages of maturity.

The chemical analyses in Table 10 illustrate a similar relationship with respect to the percentages of starch, which also are shown to be approximately the same irrespective of kernel maturity. As the endosperm is composed largely of starch, and as practically all of the starch of the corn kernel occurs in the endosperm, it is not surprising that they show similar relationships, even though they were determined by two different analytical methods, mechanical and chemical.

TABLE 10—CHEMICAL COMPOSITION OF AIR-DRIED AND ARTIFICIALLY-DRIED CORN KERNELS HARVESTED AT DIFFERENT STAGES OF MATURITY(1)

Moisture in kernels at harvest	Method of drying	Moisture	Ash	Protein	Fat	Crude Fibre	N.F.E.	* Starch
%		%	%	%	%	%	%	%
27	Air dried.....	8.59	1.46	10.70	4.50	2.21	72.54	67.0
27	108°F. 48 hrs.	8.69	1.63	11.23	4.38	2.23	71.84	65.6
32	Air dried.....	8.85	1.66	11.40	4.92	2.13	71.04	73.4
32	108°F. 48 hrs.	8.79	1.53	11.25	4.81	2.03	71.59	69.8
42	Air dried.....	9.02	1.67	10.83	4.39	2.09	72.00	69.5
42	108°F. 48 hrs.	8.75	1.56	10.80	4.22	2.02	72.65	70.6
48	Air dried.....	8.96	1.56	11.30	3.65	2.20	72.33	72.3
48	108°F. 48 hrs.	8.73	1.55	11.35	4.39	2.16	71.82	65.8

NOTE—No 58% moisture kernels were available for this analysis.

*Starch and N.F.E. values within experimental error. (1)Analysis made by the Chemical Laboratories, Science Service, Dominion Department of Agriculture, Ottawa.

It is interesting to observe in the chemical analyses of Table 10, that in addition to the starch, the percentages of the other constituents, including protein, ash, crude fibre and nitrogen-free-extract, were likewise approximately the same irrespective of maturity, and that there were no important differences between the air-dried and artificially-dried samples. Only upon the fat did maturity appear to have any noticeable effect. The percentage of fat tended to decrease in the immature as compared with the mature samples. This seems to be consistent with the following analysis of 200 germs which were excised from kernels of air-dried samples at each of the four moisture levels, 27, 32, 42 and 48 per cent, and analysed for fat content.

ANALYSIS OF CORN GERMS FOR FAT CONTENT(1)

	Moisture in kernels at harvest			
	27%	32%	42%	48%
Fat % (dry matter basis)............................	31.00	31.92	29.97	29.24

Insufficient kernels of 58% moisture for this analysis.

(1)Analysis made by Division of Chemistry, Science Service, Ottawa, Ont.

Length of Drying Period

In the actual practice of drying there is little or no purpose in reducing the moisture content of the seed below the level necessary for safe storage. To do so would be costly and useless. It is of some importance, however, to have information concerning the length of drying period and its relation to the dessication and subsequent germination of the seed.

Harrison and Wright(11) dried seed corn at 113°F. for 120 hours and reduced the moisture content to 3.4 per cent. As the seed germinated 95 per cent it was concluded that the amount of dessication did not affect the germination. Kiesselbach(19) found that ear corn subjected to the non-harmful temperature of 107°F. for 35 days reached a moisture content of 4.39 per cent and had not fluctuated more than 0.2 per cent during the preceding 28 days. The seed germinated 98 per cent, or equally as well as naturally-dried seed. He concluded that the permissible range of moisture for safe processing and storage approximates 5 to 14 per cent. According to Kienholz(17) three lots of air-dried Reids Yellow Dent ears, including diseased, 10.93 per cent moisture; badly diseased, 10.64 per cent moisture; and disease-free, 10.41 per cent moisture; were dried 100 days ~~at 100°C~~. and at the end of the drying period contained 2.23 per cent, 1.92 per cent and 2.40 per cent of moisture respectively. ~~He concluded that the last few per cent of moisture are given up very slowly even at 100°C.~~ Corn that had been kept in dessicators (sulphuric acid) for 100 days contained an average of 2.18 per cent of moisture and germinated 87 per cent after being heated for 1.5 hours at 100°C. Harrington and Crocker(10) found that the percentage of germination was not materially changed when seed of wheat, barley, sudan grass, Kentucky blue grass and Johnson grass was dried to less than 1 per cent of moisture in dessicators, using calcium oxide and also sulphuric acid. The germination of Kentucky blue and Johnson grass seed was not affected when the moisture was further reduced to 0.1 per cent, although the vigour of the seedlings was greatly reduced.

In 1942, 120 well-matured ears of Minnesota No. 13, having an average moisture content of 16.5 per cent were divided at random into 12 lots, with 10 ears in each lot. They were placed in a drying oven at 108°F. A single 10-ear sample was removed at the end of each period of 24 hours for 12 consecutive days. As each sample was removed from the oven it was immediately tested for percentage moisture. Later in the years 10 kernels were systematically removed from each ear in each of the 12 lots and these were germinated by the rag doll method. The results obtained are shown in Table 11.

TABLE 11—EFFECT OF LENGTH OF DRYING PERIOD AND DESSICATION UPON THE GERMINATION OF CORN

Ear sample	No. of days dried at 108°F.	Moisture in kernels	Germination Strong	Germination Weak
		%	%	%
Air dried	0	16.5	99	1
1	1	9.8	99	1
2	2	7.6	100	0
3	3	6.0	100	0
4	4	5.5	100	0
5	5	5.1	100	0
6	6	4.6	97	2
7	7	4.2	99	0
8	8	3.9	98	0
9	9	4.0	98	2
10	10	3.9	99	1
11	11	4.0	98	0
12	12	3.7	98	2

The data show that the moisture in the kernels was reduced rather rapidly at first and then more slowly until the seventh day, after which the moisture content remained almost constant until the end of the 12-day drying period, at which time it was 3.7 per cent.

Germination of all samples amounted to 98 per cent, or higher, and although an attempt was made to differentiate between strong and weak sprouts, with very few exceptions they were vigorous and strong in all samples.

In 1943 ears of Minnesota No. 13, with somewhat higher moisture contents, were dried in the same manner as in 1942 for periods up to 32 days. The ears were harvested on the same date from plots which had been planted at 10-day intervals, so that it was possible to obtain them at different maturities. Three separate groups of ears were harvested with 100 ears in each group. Moisture determinations were made and resulted as follows:—A group—25.2 per cent; B group—35.1 per cent; and C group—44.6 per cent. The entire collection of ears was placed in the drying oven at a temperature of 108°F. and 10 ears of each of the three groups were removed from the oven at the end of the following periods of days: 2, 4, 6, 8, 10, 12, 17, 22, 27, 32. The moisture content of each 10-ear sample was determined immediately after removal from the oven and at a later date germination and emergence tests were made by the rag doll method, and by planting in the soil in flats in the greenhouse. One hundred kernels were used from each 10-ear sample for each germination test. The moisture percentages obtained and the germination and seedling emergence results are presented in Table 12.

The data in Table 12 show that with respect to moisture content there was a rapid reduction in the percentage during the first 6 days and especially so during the first 2 days. At the end of 6 days, A group ears had lost 21.1 per cent, B group 30.7 per cent, and C group 40.0 per cent of moisture, and in all three the moisture content had reached approximately the same level, or slightly over 4 per cent During the next 26 days, loss in moisture occurred at a greatly reduced rate and amounted to only slightly over 2 per cent in all three groups, so that at the end of the 32 days drying period the moisture content was approximately 2 per cent in all ears.

Tested for germination by the rag doll method, observations made at the end of 6 days showed that the kernel samples from A and B group ears germinated equally as well as those from the air-dried ears, or 98 to 100 per cent, irrespective of the time of drying, while the germination of the C group samples varied from 81 to 91 per cent. Therefore, the length of the drying period and the reduction of kernel moisture content to almost 2 per cent had no apparent effect upon the percentage germination of the A and B group ear samples but caused a reduction in that of the C group samples.

Tested for seedling emergence in greenhouse flats with the kernels covered uniformly with one inch of firmly packed soil and held at temperatures ranging from 50°F. at night to approximately 75°F. during the day, the kernel samples from the ears of the A and B groups produced total emergence equal to that of the corresponding air-dried samples, irrespective of the length of the drying period. In comparison with the A and B group samples the high moisture C group samples were slower in starting to emerge and generally required a longer period of days in which to complete total emergence. Almost without exception emergence was most rapid in the A group samples and slowest in those of the C group at all drying periods.

As the time of drying increased from 6 to 32 days, emergence of the seedlings of all three groups tended to become more and more delayed and total emergence required a longer period to reach completion, as compared with those samples dried for the shorter periods of 2 to 4 days. A possible reason for this may have been a

TABLE 12—EFFECT OF LENGTH OF DRYING PERIOD AND DESSICATION UPON THE GERMINATION OF CORN

Classification of ears	Moisture in kernels at harvest	Air dried	No. of days dried at 108°F.									
			2	4	6	8	10	12	17	22	27	32
			Percentage of moisture content									
A group	25.2	..	10.1	6.2	4.1	3.8	4.0	3.2	3.2	2.7	2.6	2.1
B "	35.1	..	12.1	7.3	4.4	4.2	4.3	3.4	3.3	2.7	2.4	2.2
C "	44.6	..	13.7	7.4	4.6	4.5	4.4	3.6	3.4	3.2	2.7	2.2
			Percentage germination (1)									
A group	25.2	98	100	100	98	100	100	99	100	99	99	100
B "	35.1	100	99	100	98	98	99	99	98	99	98	100
C "	44.6	91	91	89	88	89	87	84	86	81	83	83

		Percentage seedling emergence (2) No. of days after planting									
	No. of days dried at 108°F.	7	8	9	10	11	12	13	14	15	Total
A group	Air dried	24	75	95	98						98
B "		4	26	63	89	100					100
C "			4	33	59	68	77	85	87	88	88
A "	2	5	48	73	94	100					100
B "		4	27	55	85	100					100
C "		4	15	46	65	73	78	80	81	83	83
A "	4		31	57	85	96	100				100
B "			14	44	71	95	100				100
C "			6	29	63	70	76	79	80		80
A "	6		29	63	84	96	99				99
B "			17	42	76	91	98	100			100
C "			4	18	56	64	72	75	79	81	82
A "	8		15	42	85	94	100				100
B "			6	27	71	87	97	100			100
C "			7	21	58	65	70	72	75	76	79
A "	10		2	33	67	90	95	98	100		100
B "				25	70	91	95	99			99
C "				12	51	64	69	73	76	77	79
A "	12			14	42	75	91	96	98		98
B "				4	30	70	88	95	100		100
C "				5	32	57	64	66	70	73	74
A "	17			14	38	74	90	93	97	99	99
B "				4	26	68	90	91	97	98	100
C "				2	25	56	64	68	71	73	75
A "	22			4	32	67	92	96	100		100
B "				2	22	71	90	93	99		99
C "				1	24	52	60	64	67	69	72
A "	27			6	27	50	78	94	98		98
B "					25	30	64	91	98		98
C "				2	21	32	51	60	66	68	70
A "	32			2	16	61	76	91	98	100	100
B "					14	47	71	84	92	98	98
C "					2	21	48	58	64	68	69

(1) Rag doll method (after 6 days).

(2) Greenhouse flats.

slowing down in the availability of the food reserves, because of a depressing effect upon the activities of the enzymes, as the drying period and the dessication continued.

The effect of maturity alone upon the rate of emergence and total emergence is clearly evident in the results obtained with the air-dried samples, although some moulding which occurred in the C group ears during the drying period after harvest may have had some effect upon their emergence.

Penetration and Retention of Heat

It is of considerable interest and importance to know something concerning the penetration and retention of heat in corn kernels of different moisture contents, when the ears are dried artificially. Large quantities of seed corn are conditioned for storage by artificial drying every year and at the temperatures commonly recommended and used, 105°F. to 110°F., no harm is done to corn that has been harvested in a well-matured condition. If the corn is immature, containing over 40 per cent of moisture at harvest, immediate artificial drying may seriously damage its germination or its vitality.

Harrison and Wright(11), after drying corn at high temperatures, reported that the lower the initial moisture the greater the damage during the early period of drying, because of the quicker penetration of heat in low-moisture corn. Just(16) found that red clover seeds lost their germination after being exposed in a saturated atmosphere for one hour at 75°C., while it required 120°C. to kill the germination when the water content was withdrawn during the drying process.

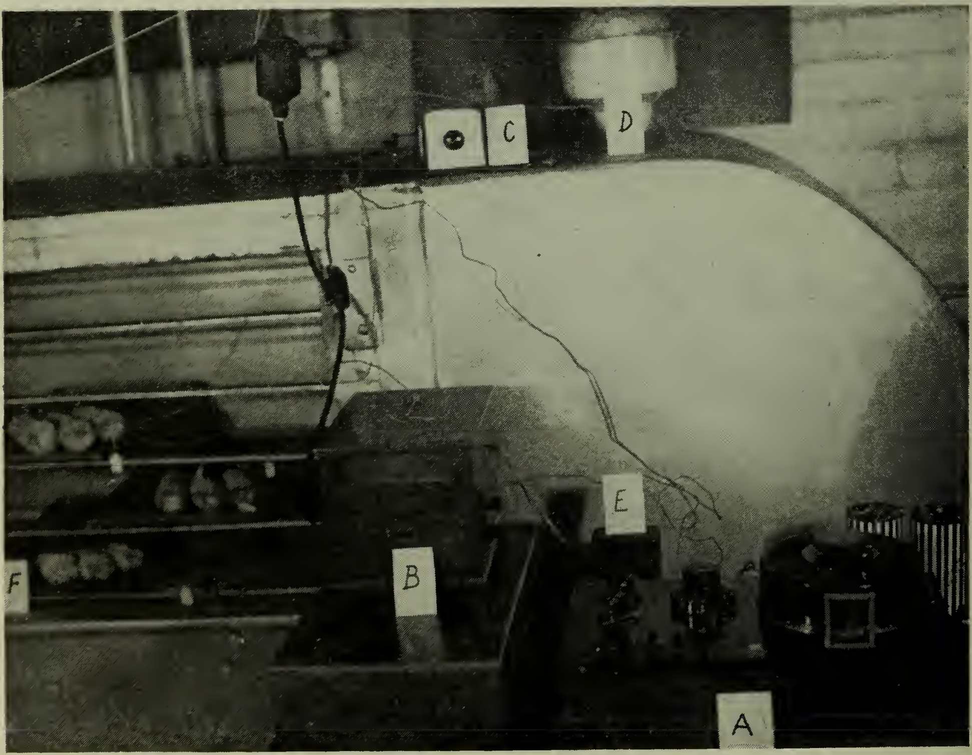


Fig. 6. Thermocouple test apparatus.
A) Potentiometer. B) Galvanometer. C) Control switch. D) Cold junction. E) Standard cell. F) Copper-constantan thermocouples and ear samples.

To obtain some information on the penetration of heat and its retention during artificial drying, three samples of ears of the Minnesota No. 13 variety, averaging 25.2, 34.4, and 54.8 per cent of moisture in the kernels respectively, were tested by using copper-constantan thermocouples. The arrangement of the apparatus required for the making of the thermocouple tests is illustrated in Fig. 6. A standard chart was used for the conversion of the potentiometer readings to degrees Centigrade and Fahrenheit.

The temperature of the drying oven was thermostatically controlled with a differential of 13°F. between a high and low temperature of 112°F. to 99°F. respectively. Operating at this setting it required seven minutes to raise the temperature from low to high, and thirteen minutes to drop from high to low. The wide differential of 13°F. between high and low was preferred to a narrower range because it provided ample time for thermocouple readings to be made without too rapid changes in temperatures. It required approximately five minutes to complete each of the potentiometer readings of the nine ears.

As nine ears were tested at the same time, three ears were taken at random from among those harvested at each of the three stages of maturity. Small holes, the size of the thermocouple points were drilled through the centre of a row of kernels on each ear, from the base extending about one-third the distance to the tip. Into this hole the thermocouple point was inserted tightly. The ears were connected to the thermocouple switch in the following order: 1, 4, 7,—immature, 54.8 per cent moisture; 2, 5, 8—mature, 34.4 per cent moisture; 3, 6, 9,—well matured, 25.2 per cent moisture. Readings were made consecutively from ear 1 to ear 9.

The temperature observations obtained by using the thermocouple are presented in Table 13. Graphs constructed on the basis of the data included in the table are shown in Fig. 7 (a,b,).

The first series of readings covered a period of 48 hours, at the end of which time kernels removed from the ears were tested for moisture with the following results: well-matured kernels, 9.2 per cent; matured kernels, 10.9 per cent; and immature kernels, 12.3 per cent of moisture. The moisture contents indicated that the ears were dried somewhat beyond the stage required for safe storage.

The first 11 readings were made at fifteen-minute intervals while the remaining readings were spaced at longer intervals during the rest of the two-day drying period. During the first hour of drying the temperature of the kernels in all three samples rose sharply and uniformly, with the well-matured kernels showing the highest temperatures and the immature kernels the lowest. This relationship was maintained almost continuously throughout the entire drying period as is illustrated by the charted temperatures in the graph. The high and low points show a greater rise and fall of temperature in the more mature kernels as compared with the immature, indicating that the high-moisture kernels maintained a somewhat more uniform temperature throughout, than the low-moisture kernels. It required approximately an hour for the well-matured kernels to reach the minimum temperature of the drying chamber, while the mature kernels required almost two hours and the immature kernels three hours to reach the same temperature. During the first three hours, which included readings 1 to 11, temperatures of the well-matured kernels exceeded 100°F. four times, the matured kernels once and the immature kernels not at all. After the first three hours the kernel temperatures for all samples were above 100°F. at all readings with one exception, when all three were slightly below it. The average kernel temperatures for all readings were as follows: well-matured, 98.5°F.; matured, 96.9°F.; and immature, 95.8°F.

The second series of readings were obtained during a period of 24 hours only. Kernels tested for moisture at the end of this time showed the following: well-matured, 14 per cent; matured, 21.6 per cent; and immature, 35.6 per cent of moisture.

TABLE 13—TEMPERATURES OF CORN KERNELS OF DIFFERENT MOISTURE CONTENTS DURING ARTIFICIAL DRYING AT 99°F.-112°F.

Series I

Period of drying, 48 hours

Readings	Hours of drying	Immature ears, Kernels 54.8% m.	Matured ears, Kernels 34.4% m.	Well-matured ears, Kernels 25.2% m.
		°F.	°F.	°F.
1	¼	67.1	68.7	74.8
2	½	80.6	82.4	86.1
3	¾	89.7	91.0	93.1
4	1	96.3	97.0	100.9
5	1¼	94.4	93.2	94.3
6	1½	92.2	94.6	102.4
7	1¾	98.9	98.9	100.6
8	2	99.2	101.2	102.9
9	2¼	97.6	99.0	98.2
10	2½	93.9	93.7	94.2
11	2¾	101.4	101.9	101.2
12	19	104.7	105.9	106.7
13	21	101.6	101.6	101.9
14	24	96.6	97.4	97.6
15	27	101.1	104.7	105.2
16	43	100.3	101.4	101.8
17	45	101.8	101.8	102.2
18	48	106.5	109.5	109.5
	Average.........	95.8	96.9	98.5

Series 2

Period of drying, 24 hours

Readings	Hours of drying	Immature ears, Kernels, 54.8% m.	Matured ears, Kernels, 34.4% m.	Well-matured ears, Kernels 25.2% m.
		°F.	°F.	°F.
1	¼	67.9	69.9	77.3
2	½	84.7	86.3	87.1
3	¾	90.7	92.8	94.8
4	1	95.4	97.4	99.3
5	2	96.8	99.3	100.6
6	3	98.4	99.3	101.8
7	4	95.3	93.0	93.1
8	6	95.8	95.1	97.2
9	8	90.5	90.8	92.8
10	10	94.2	96.3	100.0
11	12	97.5	98.1	100.8
12	22	91.1	91.0	90.0
13	23	99.8	100.8	104.5
14	24	97.1	97.2	96.9
	Average.........	92.5	93.4	95.4

Fig. 7. (a) Temperatures obtained in corn kernels during artificial drying at 99°-112° F. for 48 hours.

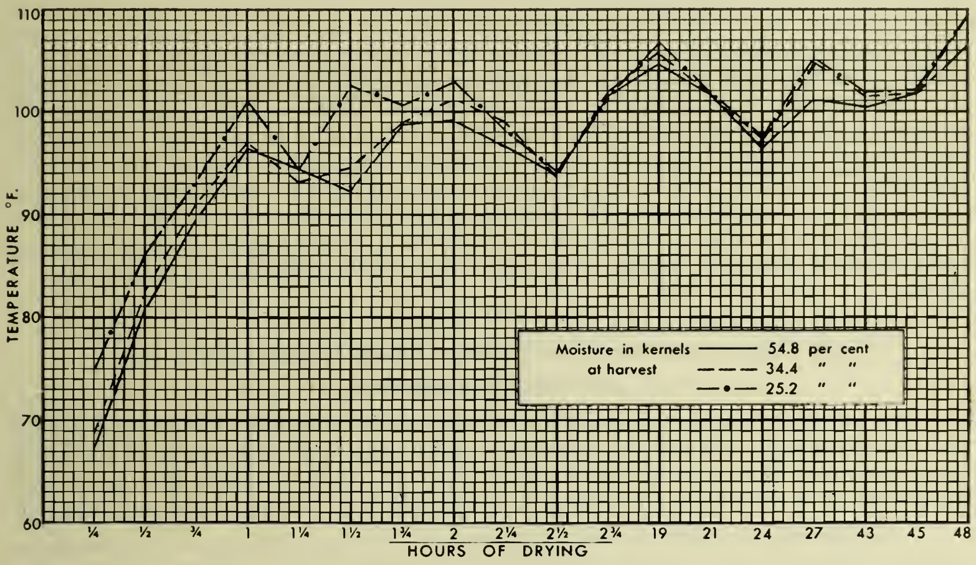
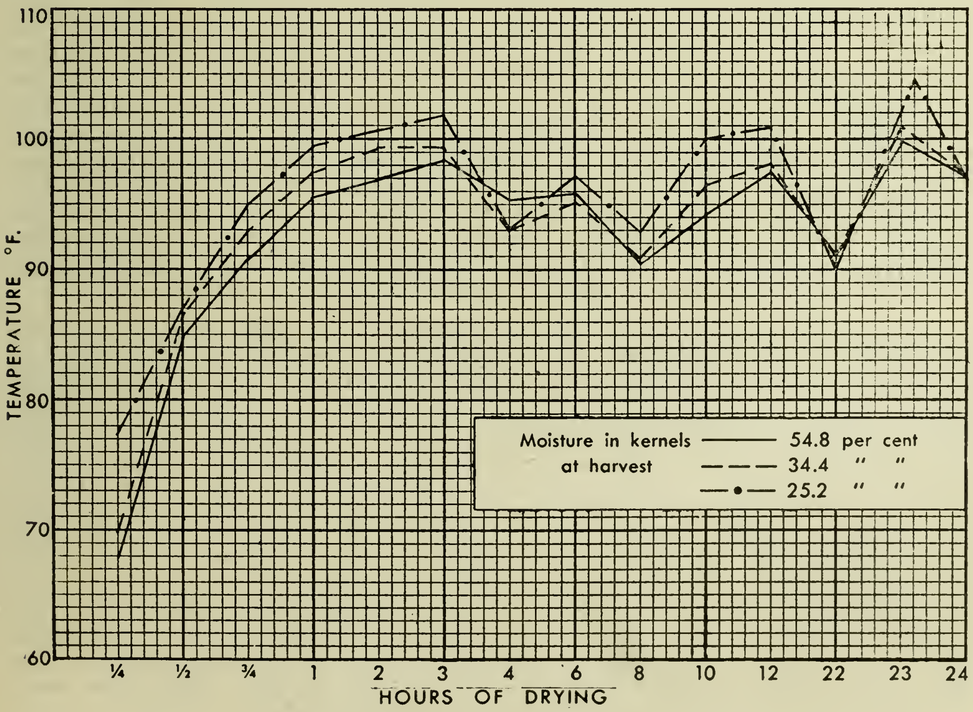


Fig. 7. (b) Temperatures obtained in corn kernels during artificial drying at 99° F.-112° F. for 24 hours.



The first four readings were made at 15-minute intervals, while the remaining readings were spaced at longer intervals during the remainder of the 24-hour period. The general trend of the temperatures during the first hour was very similar to those of Series 1. The well-matured kernels showed the highest temperatures and the immature kernels the lowest. While the temperatures during this period rose rapidly and uniformly none of them quite reached 100°F. During the next 23 hours the well-matured kernels showed temperatures of 100°F. or higher five times, the matured kernels once and the immature kernels not at all. As in Series 1, the immature kernels tended to maintain a more uniform temperature than either the well-matured or matured. The average temperatures for all readings during the 24-hour period were: well-matured, 95.4°F.; matured, 93.4°F.; and immature 92.5°F. These temperatures were slightly below those of Series 1, where higher average temperatures resulted from the higher levels that were reached during the second day of drying.

High Temperatures—Their Effect Upon Germination and Seedling Emergence

The effect of heat in the treatment of seed varies according to the kind of seed and the temperatures used. In the case of some seeds high temperatures are sometimes necessary before germination can take place, while in others the use of high temperatures is disastrous, resulting in severe injury or killing of the seed entirely.

In experiments conducted by Harrison and Wright(11) corn was harvested at various moisture levels and dried at different temperatures. They reported that ear corn dried by forced warm air at 104°F. to 113°F. was not injured; at 122°F. it was considerably damaged; at 140°F. it was nearly all killed and at 158°F. it was completely killed.

Ullstrup and Wileman(29) found that seed corn with an initial moisture content of less than 25 per cent may be dried at temperatures of 120°F. without danger of impairing the germination of the seed. DeOng(5) exposed 5 varieties of corn for 8 hours at 120°F. and obtained normal germination, while Burgess(4) found that corn which germinated 94 per cent suffered reduction in viability to 68 and 32 per cent respectively when heated at 176°F. for periods of 1 and 3 hours. According to Washko (31) the drying temperature that can be used without injury to viability is largely determined by the maturity and moisture content of the corn. Corn varying from 17.9 to 48.4 per cent of moisture was injured at 125°F., while at 120°F. injury was less evident, and at 115°F. injury only occurred when the initial moisture level approximated 40 per cent or higher. Weaver and Clements(30) state that it is probable that most seeds commonly used in our agriculture are injured to a greater or lesser extent by the application of high temperatures.

In the experiment reported here well-matured ears of Minnesota No. 13 were harvested from two plots which had been planted in the spring at intervals of 10 days apart. Altogether, 250 ears were taken from each plot, these being harvested in lots of 50 ears on five consecutive days. Moisture determinations made immediately after harvesting showed that the five-ear lots from the plot planted first contained 22.5, 22.2, 22.7, 22.5, and 22.6 per cent of moisture respectively for an average of 22.5 per cent, while those from the plot planted 10 days later contained 26.1, 26.4, 25.8, 26.2 and 25.6 per cent of moisture for an average of 26.0 per cent.

The temperatures used in drying were 110°F., 120°F., 130°F., 140°F. and 150°F. The maximum time of drying at each of these five temperatures was 24 hours. At the beginning of each drying period 40 ears, together with approximately 2½ pounds of shelled corn from 10 ears, chosen at random from each 50-ear lot, at both the 22.5 and 26.0 per cent moisture levels, were placed in the drying oven. At the end of 6, 12, 18 and 24 hours, 10 ears and one-half pound of shelled corn were removed from each of the two lots and stored in paper bags.

During the winter, germination and emergence tests were made using the rag doll method and greenhouse flats respectively. One hundred seeds taken at random from the ears and from the shelled corn were used for each of the tests. The kernels in the greenhouse flats were uniformly covered with one inch of firmly packed soil and held at an average temperature of 50° to 75°F. during the night and day respectively. The results obtained are presented in Tables 14 and 15.

TABLE 14—EFFECT OF DRYING AT HIGH TEMPERATURES UPON THE GERMINATION OF CORN

RAG DOLL GERMINATION

TEMPERATURE OF DRYING

Shelled or in ear	Duration of drying	Air dried		110°F.		120°F.		130°F.		140°F.		150°F.	
		T.	S.	T.	S.	T.	S.	T.	S.	T.	S.	T.	S.
		%	%	%	%	%	%	%	%	%	%	%	%
				Kernels with 22.5% moisture at harvest									
Ear	.....	100	100										
Shelled	6 hrs.			100	100	98	98	100	92	86	68	58	48
Ear	6 "			100	100	100	100	100	96	100	94	90	68
Shelled	12 "			99	99	100	100	98	94	88	72	62	42
Ear	12 "			100	100	100	100	98	96	93	79	72	54
Shelled	18 "			100	100	100	100	96	96	90	78	72	46
Ear	18 "			100	100	100	100	100	100	90	74	64	40
Shelled	24 "			99	99	98	98	97	94	74	60	26	14
Ear	24 "			100	100	100	94	100	94	74	66	48	28
				Kernels with 26.0% moisture at harvest									
Ear	.....	99	97										
Shelled	6 hrs.			100	100	100	100	97	91	74	44	18	8
Ear	6 "			99	99	100	100	98	90	92	72	82	48
Shelled	12 "			100	100	100	90	92	88	76	48	20	12
Ear	12 "			100	100	100	92	94	89	92	75	36	28
Shelled	18 "			100	98	96	92	88	75	68	34	16	10
Ear	18 "			100	100	100	100	86	74	68	38	4	4
Shelled	24 "			99	97	96	91	90	84	52	46	0	0
Ear	24 "			100	98	100	98	100	86	50	36	5	3

T = total S = strong.

According to the results obtained in the rag doll tests, shown in Table 14, the germination of the corn samples which originally contained 22.5 per cent of moisture, was not much damaged until the temperature of drying reached 140°F. Even at this temperature the total germination was still quite high in all samples except those dried for the longest period, which was 24 hours. Although the germination was still high, however, there was a marked increase in the number of weakly-sprouted kernels: At 150°F. the total germination of all samples dropped sharply and at the same time the number of weak sprouts increased still more.

The 26.0 per cent moisture corn was not seriously affected by drying at 120°F. but at 130°F. the total germination was lowered considerably in most samples, and the percentage of weakly-sprouting kernels increased. Drying at 140°F. caused a sharp drop in total germination and a marked increase in weak sprouts, while at 150°F. germination was very low in all samples with a still further increase in the number of weak sprouts produced.

That the results obtained from the testing of the corn samples in greenhouse flats did not entirely agree with those of the rag doll tests is indicated in the data presented in Table 15, although it is quite possible that had those kernels which germinated but did not emerge been counted the two results might have been more in agreement. The influence of drying is measured here by seedling emergence rather than by germination alone, as in the rag doll test, and the effect of the drying temperatures upon the vigour of the young seedlings is more evident. Obviously, many of the weak sprouts were unable to push to the surface and emerge from the soil, and it is clear that drying of the two well-matured corn lots, containing 22.5

TABLE 15—EFFECT OF DRYING AT HIGH TEMPERATURES UPON THE SEEDLING EMERGENCE OF CORN

Shelled or in ear	Duration of drying	Temp. of drying	Moisture in kernels at harvest	Seedling emergence No. of days after planting											
				9	10	11	12	13	14	15	16	17	18	Total	13th day
			%	%	%	%	%	%	%	%	%	%	%	%	%
Ear......	Air dried		22.5	11	33	55	84	99						99	99
"	" "		26.0	8	29	52	83	100						100	100
Shelled...	6 hrs.	110°F.	22.5	8	24	52	79	98	99					99	98
Ear......	6 "	"	"	9	34	50	83	97	100					100	97
Shelled...	12 "	"	"	8	22	47	78	96	98	99				99	96
Ear......	12 "	"	"	8	29	53	79	99						99	99
Shelled...	18 "	"	"	5	24	44	74	96	97	98	99			99	96
Ear......	18 "	"	"	9	29	49	76	96	100					100	96
Shelled...	24 "	"	"	8	22	45	72	96	98					98	96
Ear......	24 "	"	"	7	26	45	76	95	99					99	95
Shelled...	6 "	"	26.0	9	25	48	78	96	99					99	96
Ear......	6 "	"	"	8	31	49	81	97	98	99	100			100	97
Shelled...	12 "	"	"	6	26	44	74	97	98	99				99	97
Ear......	12 "	"	"	8	28	51	78	98	99					99	98
Shelled...	18 "	"	"	6	27	45	71	94	96	98	99			99	94
Ear......	18 "	"	"	7	30	46	74	97	99					99	97
Shelled...	24 "	"	"	7	27	42	73	95	97	98				98	95
Ear	24 "	"	"	5	26	45	76	96	97	99				99	96
Shelled...	6 "	120°F.	22.5	4	22	34	60	79	86	96	99			99	79
Ear......	6 "	"	"	9	37	49	86	98	100					100	98
Shelled...	12 "	"	"	5	24	41	68	94	98	99				99	94
Ear......	12 "	"	"	8	36	51	82	97	99					99	97
Shelled ..	18 "	"	"	4	11	21	48	55	63	75	77	78	85	85	55
Ear......	18 "	"	"	4	19	36	59	84	96					96	84
Shelled...	24 "	"	"		5	21	39	63	71	78	81	82		82	63
Ear......	24 "	"	"		4	21	50	81	94	100				100	81
Shelled...	6 hrs.	120°F.	26.0	4	17	42	66	74	86	90	99			99	74
Ear......	6 "	"	"	8	29	51	76	80	86	96				96	80
Shelled...	12 "	"	"	4	10	18	41	61	64	65	71	74	76	76	61
Ear......	12 "	"	"	2	11	50	84	91	96	99				99	91
Shelled...	18 "	"	"		5	18	39	50	59	65	70	73	74	74	50
Ear......	18 "	"	"	1	12	42	68	88	92	96	98			98	88
Shelled...	24 "	"	"		6	21	39	48	60	71	71	73	75	75	39
Ear......	24 "	"	"			6	22	51	74	97				97	22
Shelled...	6 hrs.	130°F.	22.5			6	27	54	75	94	95	96		96	54
Ear......	6 "	"	"		9	26	46	62	80	93	96	100		100	62
Shelled...	12 "	"	"			3	30	72	86	94	96	97		97	72
Ear......	12 "	"	"		5	17	30	66	84	95	98			98	56
Shelled...	18 "	"	"			1	29	66	77	84	89	91		91	66
Ear......	18 "	"	"		9	17	26	64	83	99				99	64
Shelled...	24 "	"	"			1	14	49	74	78	81	86	87	87	49
Ear......	24 "	"	"			1	28	56	79	88	95	98		98	56
Shelled...	6 "	"	26.0				12	52	70	85	89			89	52
Ear......	6 "	"	"			5	13	46	71	89	96			96	46
Shelled...	12 "	"	"				3	15	44	59	78	80	82	82	15
Ear......	12 "	"	"			5	12	42	68	80	85	90		90	42
Shelled...	18 "	"	"					6	20	36	60	72	79	79	6
Ear......	18 "	"	"				1	5	33	64	71	76	80	80	5
Shelled...	24 "	"	"					4	21	35	59	74	78	78	4
Ear......	24 "	"	"					5	31	54	68	76	84	84	5
Shelled...	6 "	140°F.	22.5			4	11	21	49	56	68	76		76	21
Ear......	6 "	"	"			5	19	39	74	84	94			94	39
Shelled...	12 "	"	"					19	39	70	78			78	19
Ear......	12 "	"	"				11	31	59	76	93			93	31
Shelled...	18 "	"	"				4	19	44	54	69	71	72	72	19
Ear......	18 "	"	"					15	24	36	59	66	74	74	15
Shelled...	24 "	"	"					4	17	25	44	54		54	4
Ear......	24 "	"	"					5	16	26	45	62	69	69	5
Shelled...	6 hrs.	140°F.	26.0				5	14	26	36	44	52		52	14
Ear......	6 "	"	"			5	7	38	62	70	72	78	81	81	38
Shelled...	12 "	"	"					11	16	28	39	44	47	47	9
Ear......	12 "	"	"			6	13	29	44	72	79	81	82	82	33
Shelled...	18 "	"	"					14	33	40	46	48		48	14
Ear......	18 "	"	"					12	44	56	62	64		64	28
Shelled...	24 "	"	"						5	24	34	38		38	0
Ear	24 "	"	"						4	21	32	38	42	42	0
Shelled...	6 hrs.	150°F.	22.5					19	30	39	46	50		50	19
Ear......	6 "	"	"				5	39	61	74	78			78	39
Shelled...	12 "	"	"					3	28	37	45	51		51	3
Ear......	12 "	"	"					6	29	44	52	57		57	6
Shelled...	18 "	"	"						9	20	29	36		36	0
Ear......	18 "	"	"					4	15	49	54			54	4
Shelled...	24 "	"	"							1	7	8		8	0
Ear......	24 "	"	"						9	24	34	39		39	0
Shelled...	6 hrs.	150°F.	26.0						2	5	12	13	14	14	0
Ear......	6 "	"	"				5	24	36	49	57	66	74	74	24
Shelled...	12 "	"	"						5	7	10	12		12	0
Ear......	12 "	"	"						4	7	16	22	26	26	0
Shelled...	18 "	"	"							2	8	9		9	0
Ear......	18 "	"	'								1			1	0
Shelled...	24 "	"	"											0	0
Ear......	24 "	"	"						1	2	4			4	0

per cent and 26.0 per cent of moisture respectively, at temperatures above 110°F., had a damaging effect upon seedling vigour, the extent of the damage increasing with each increase in the time of drying, as well as in the temperature. The results are well illustrated in Fig. 8.

Dried at 110°F., seedling emergence was almost as rapid and total emergence as high as in the air-dried material. This was true of the corn at both moisture levels, 22.5 per cent and 26.0 per cent, and irrespective of the time of drying or whether the corn was dried shelled or on the ear. Five days after emergence began, or 13 days after planting, there was over 90 per cent seedling emergence in all of the 16 samples, which was equally as good as in the air-dried corn. As the time required for seedling emergence may be regarded as a good indication of seedling vigour, it appears safe to conclude that the vigour of the seedlings of the corn dried at 110°F. was equal to that of the air-dried corn, and that no injury was done to the kernels by drying at this temperature.

Drying at 120°F. for periods up to 24 hours was not harmful to seed dried on the ear, except for a slight delay in seedling emergence and slight reduction in seedling vigour, both of which were somewhat more marked in the 26.0 per cent

TABLE 16—EFFECT OF DRYING AT HIGH TEMPERATURES UPON THE SEEDLING EMERGENCE OF CORN. (Summary of data presented in Table 15)

Shelled or in ear	Total kernels planted	Seedling emergence		Seedlings emerged 13 days after planting		
		Total	% of kernels planted	Total	% of kernels planted	% of total emergence
		Air dried, 22.5% moisture				
Ear	100	99	99	99	99	100
		Air dried, 26.0% moisture				
Ear	100	100	100	100	100	100
		Artificially dried, 110°F. 22.5% moisture				
Shelled(1)	400	395	98.8	386	96.5	97.7
Ear(1)	400	398	99.5	387	96.8	97.2
				26.0% moisture		
Shelled	400	395	98.8	382	95.5	96.7
Ear	400	397	99.3	388	97.0	97.7
		Artificially dried, 120°F. 22.5% moisture				
Shelled	400	365	91.3	291	72.8	79.7
Ear	400	395	98.8	360	90.0	91.1
				26.0% moisture		
Shelled	400	324	81.0	233	58.3	71.9
Ear	400	395	97.5	310	77.5	79.5
		Artificially dried, 130°F. 22.5% moisture				
Shelled	400	371	92.8	241	60.3	65.0
Ear	400	395	98.8	248	62.0	62.8
				26.0% moisture		
Shelled	400	328	82.0	77	19.3	23.5
Ear	400	350	87.5	98	24.5	28.0
		Artificially dried, 140°F. 22.5% moisture				
Shelled	400	280	70.0	63	15.8	22.5
Ear	400	330	82.5	90	22.5	27.3
				26.0% moisture		
Shelled	400	185	46.3	39	9.8	21.1
Ear	400	269	65.0	79	19.8	29.4
		Artificially dried, 150°F. 22.5% moisture				
Shelled	400	145	36.3	22	5.5	15.2
Ear	400	228	57.0	49	12.3	21.5
				26.0% moisture		
Shelled	400	35	8.8	0	0.0	0.0
Ear	400	105	26.3	24	6.0	22.9

(1)Shelled and ear samples comprised of 100 kernels from each of the four drying periods.

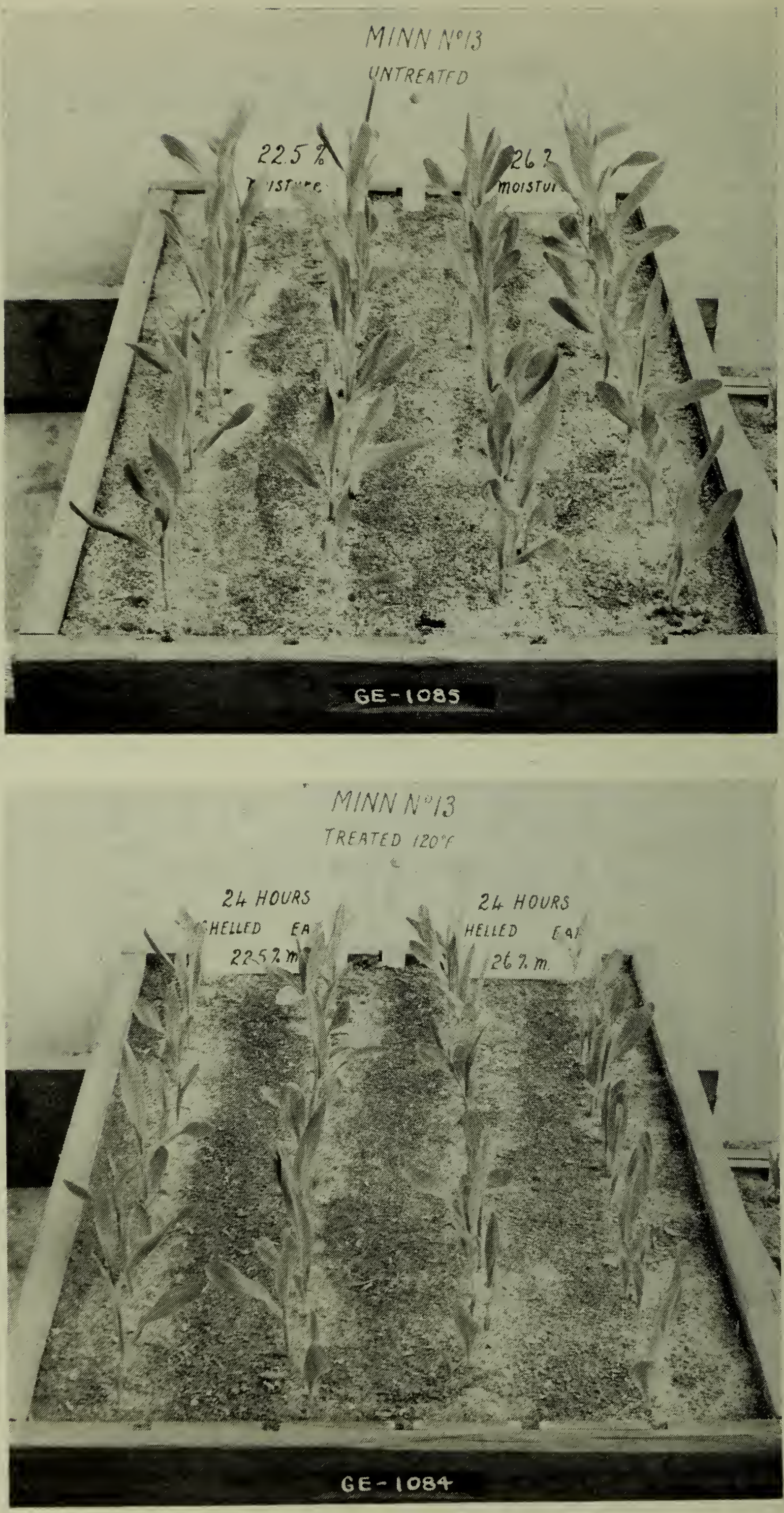


Fig. 8. Seedling emergence of well matured seed (22.5 and 26.0 per cent moisture at harvest), air dried and artificially dried at high temperatures.

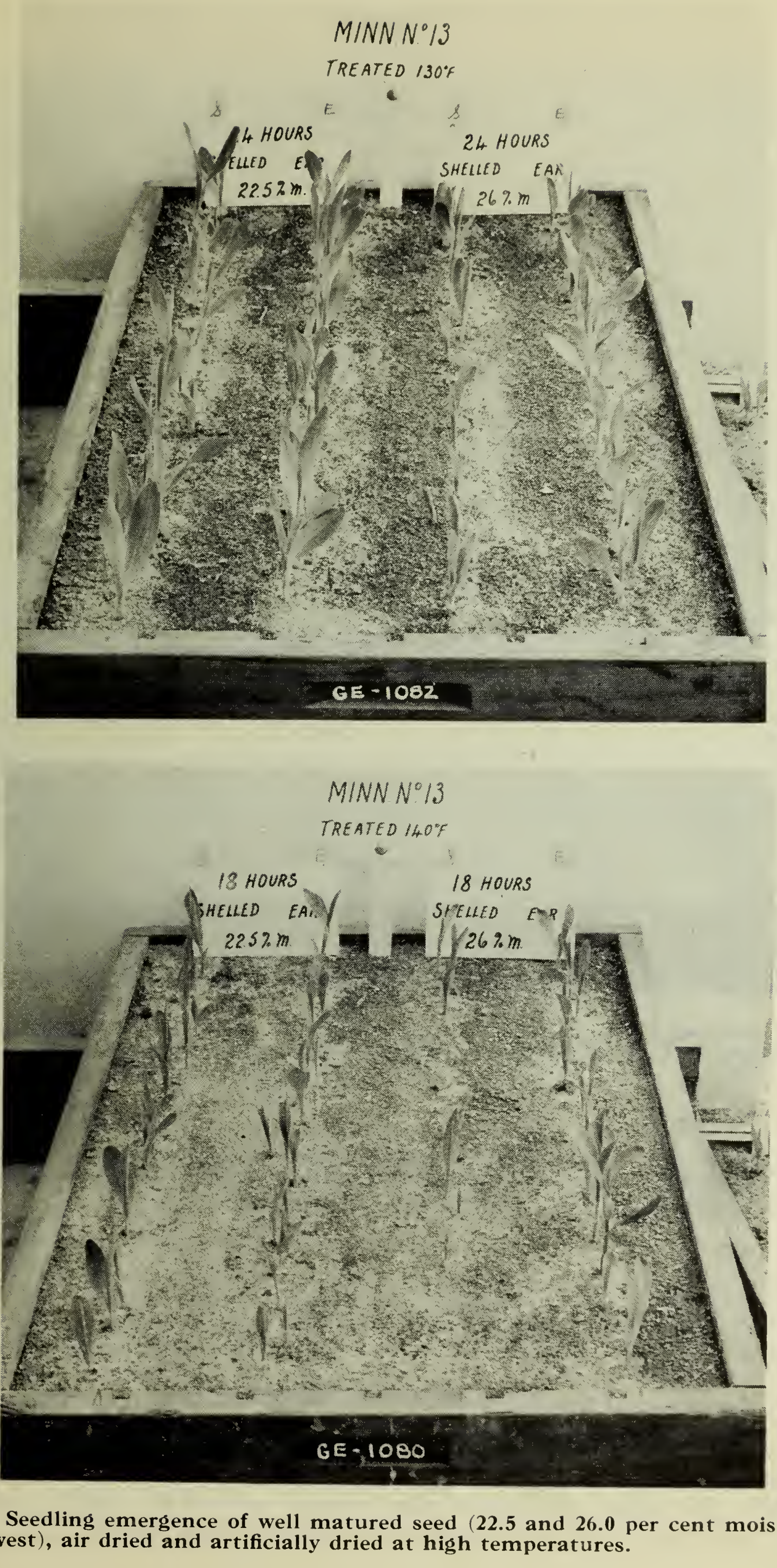


Fig. 8. Seedling emergence of well matured seed (22.5 and 26.0 per cent moisture at harvest), air dried and artificially dried at high temperatures.

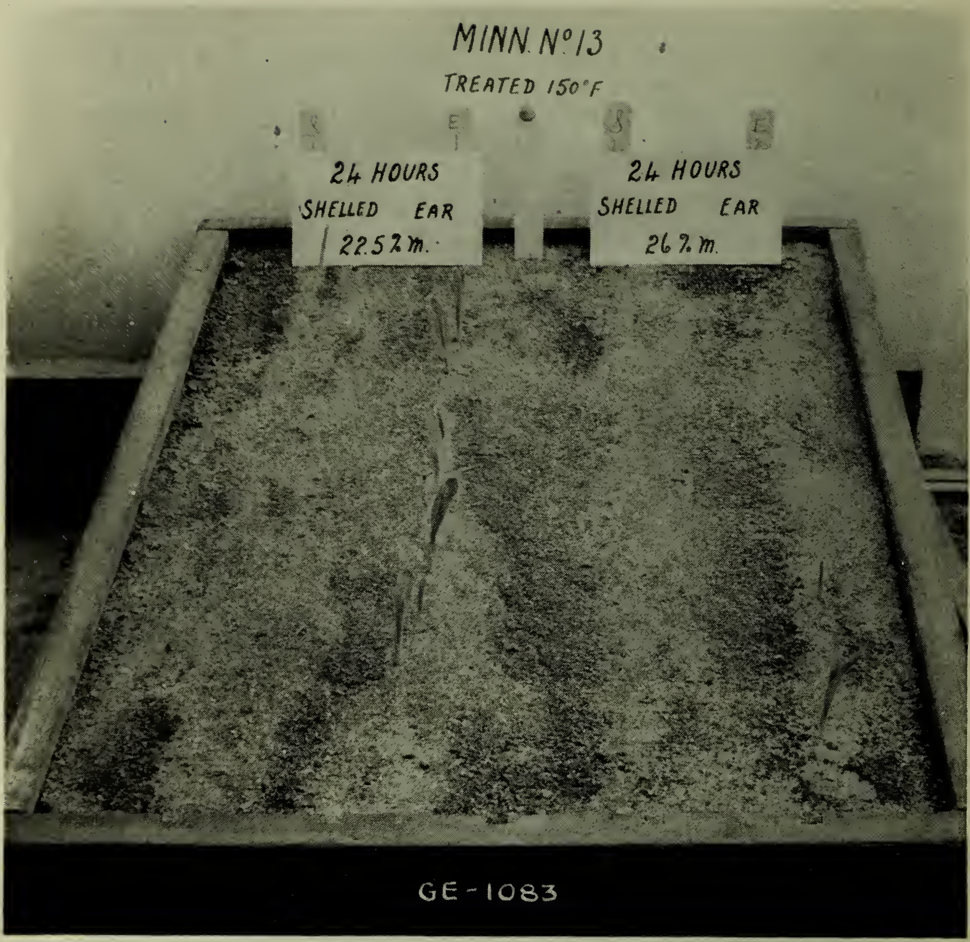


Fig. 8. Seedling emergence of well matured seed (22.5 and 26.0 per cent moisture at harvest), air dried and artificially dried at high temperatures.

than in the 22.5 per cent moisture corn. Total emergence was equally as high as in the air-dried seed. In the shelled corn, drying at this temperature for periods in excess of 6 hours caused greatly retarded seedling emergence, and seriously reduced the total emergence of most samples at both moisture levels.

Drying at 130°F. and 140°F. seriously affected both the total emergence and the rapidity of emergence of nearly all samples. While some lots at the shorter periods of drying produced a high total emergence, the emergence of the seedlings was greatly retarded, so that 13 days after planting the percentage of seedling emergence was much lower than in the air-dried material and the samples dried at 110°F. This is indicated by the data in Table 16, which show that the total emergence of all samples at the 22.5 moisture level dried at 130°F. was almost equal to that of the air-dried and artificially-dried at 110°F. But whereas seedling emergence of the samples of the latter two lots was approximately 96.7 per cent at the end of 13 days, the average was only 61.2 per cent at the same time for the samples dried at 130°F. The higher temperatures had seriously affected the vigour of the seedlings, even though the final total emergence was not much reduced.

Drying at 150°F. was most injurious to the corn both from the standpoint of its effect upon total emergence and the rate of emergence. The data obtained in the rag doll test showed that even at the shorter drying periods the germination was reduced with two exceptions to about 70 per cent, or lower, while at the longer drying periods it was reduced in most samples to below 30 per cent. In one sample germination failed completely. The high temperature had a very marked effect upon time of emergence and total emergence of the seedlings when grown in greenhouse flats. Thirteen days after planting only 22 seedlings, or 5.5 per cent of the entire shelled corn samples, and only 49 or 12.3 per cent of the ear corn samples at the 22.5 per cent moisture level had emerged, while none of the shelled corn samples, and only 24, or 6.0 per cent of the ear corn samples, had emerged at this time in the 26.0 per cent moisture corn.

Differential Response of Inbred Lines to Artificial Drying

In the breeding of corn, inbred lines are retained or rejected on the basis of their resistance to disease, lodging, drought, heat, cold, etc., as well as their ability to combine well to produce high-yielding hybrids.

In this particular study attention was directed to their differential response to artificial drying, when the ears were harvested at different stages of maturity, response being measured by the effects of the drying upon the germination of the seed and the vigour of the seedlings.

Ullstrup and Wileman(29) report no indication of differential susceptibility to heat injury on the part of various inbreds, single crosses and double crosses. All lines behaved the same way with respect to heat tolerance. By testing strains at comparable levels of initial moisture, Washko(31) found that inbred lines were more subject to heat injury than single- and double-cross hybrids.

Thirty-six inbred lines, all of which had been selfed for five years or more, were sown and at least thirty plants of each line were self-pollinated. The inbreds included both flint and dent types, were extremely uniform for all visible plant and ear characters, and were selected because of their vigourous, thrifty habit of growth.

Harvesting was done at four different dates in order to obtain ears containing approximately 50, 40, 30 and 20 per cent of moisture in the kernels. Six ears were harvested at each of the moisture levels and from these ears kernels were sampled immediately for the determination of moisture content. Of the six ears comprising each sample, three were air dried and three were artificially dried at 108°F. for 48 hours. As only 24 of the 36 lines yielded the full complement of six ears at each of the four moisture levels, the remaining 12 lines were eliminated from further study.

The average moisture content of the 24 lines at the four levels of moisture was 49.5, 40.1, 29.6 and 20.2 respectively. The extent to which the kernel moisture content of the individual ear samples varied from the desired moisture levels of 50, 40, 30 and 20 per cent was found to be as follows:—

Moisture levels desired %	Extent of variation in the kernel moisture content of 24 lines from the desired moisture levels				
	±0.0–1.0 %	±1.1–2 %	±2.1–3.0 %	±3.1–4.0 %	±4.1–5.0 %
50	14	6	1	1	2
40	18	6			
30	15	8	1		
20	21	3			

The widest variation from the desired moisture content occurred in the samples at the 50 per cent level, although even at this level 20 of the 24 samples varied to the extent of less than 2.0 per cent. At the other three levels all of the samples, with one exception, varied less than 2.0 per cent from the desired levels. Sampling of the ears, therefore, was highly satisfactory.

In order to study the effects of kernel moisture content and the response of the different inbreds to artificial drying, 100 kernels were taken at random from the air-dried and artificially-dried ear samples at each of the moisture levels. Fifty kernels were used for the rag doll germination test and 50 were planted in the field to obtain emergence data. In the field planting, single kernels were dropped six inches apart in the rows at a uniform depth of 1½ inches, and covered evenly with soil by using a hand rake. The rag doll counts were taken after a period of 6 days, while in the field the first emergence records were taken after 8 days and the final or total counts after a further period of 12 days.

The complete data for kernel moisture, rag doll germination and field emergence of the 24 lines are included in Appendix Table I. A summary of these data is presented in Table 17.

TABLE 17—SUMMARY OF DATA OBTAINED FROM 24 INBRED LINES, SHOWING AVERAGES FOR KERNEL MOISTURE CONTENT, RAG DOLL GERMINATION AND FIELD EMERGENCE OF AIR-DRIED AND ARTIFICIALLY-DRIED KERNELS

No. of inbreds	Moisture in kernels at harvest	Rag doll germination(1) (after 6 days)						Field emergence (after 8 days)			
		Air-dried			Artificially-dried(2)			Air-dried		Artificially-dried(2)	
		S.	W.	T.	S.	W.	T.	8 days	Total	8 days	Total
	%	%	%	%	%	%	%	%	%	%	%
24	49.5	72	15	87	48	28	76	70	75	39	45
24	40.1	86	9	95	67	20	87	81	86	70	77
24	29.6	89	7	96	82	13	95	85	88	86	89
24	20.2	91	6	97	85	10	95	86	89	86	90

(1) S—Strong. W—Weak. T—Total.

(2) Artificially dried at 108°F.

As was found in the case of the variety, Minnesota No. 13, the general effect of immaturity in the air-dried material was to lower the percentage germination slightly and to increase the percentage of weak or less vigorous sprouts. The same effect was apparent in both the rag doll test and the field emergence test, particularly at the 49.5 per cent moisture level. In the field test the percentage of emergence in the high-moisture kernels, 49.5 and 40.1 per cent, at the end of 8 days was lower in relation to the total emergence than in the low-moisture kernels, 29.6 and 20.2 per cent.

In comparing the air-dried with the artificially-dried samples there was very little difference in the behaviour of the two low-moisture samples, 29.6 and 20.2 per cent, in either the rag doll germination or field emergence tests. The percentage of germination was high, and the early emergence and total emergence were likewise high in both samples. In the two high-moisture samples, artificial drying resulted in lowering the germination and increasing the percentage of weak sprouts in the rag doll tests, and reducing the total emergence and the rate of emergence in the field tests, as compared with the air-dried samples.

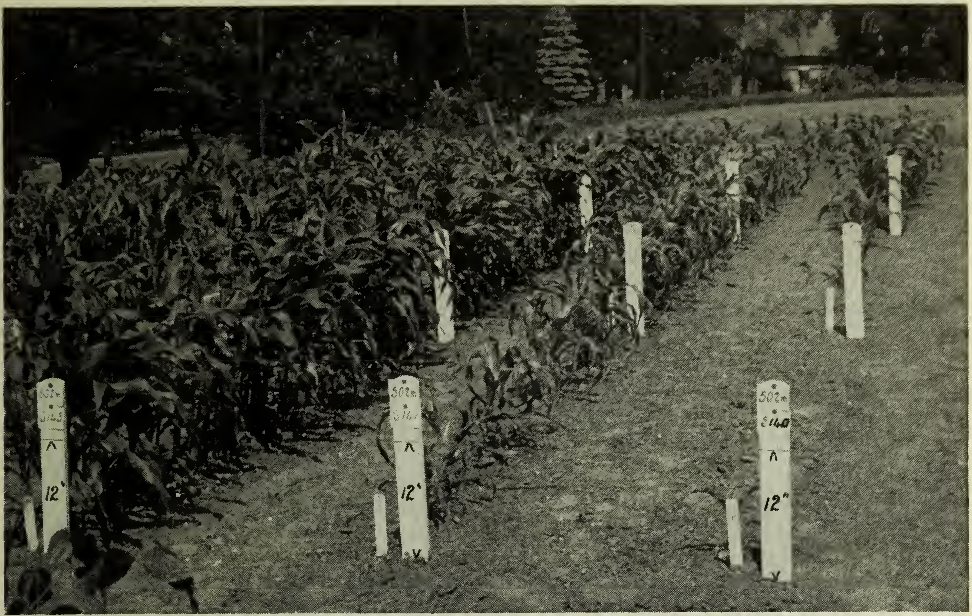


Fig. 9. Inbreds 140, 141, and 143. Showing differential response of inbreds to artificial drying of seed harvested at different maturities.

Individual inbreds showed considerable variation in the effects of kernel moisture and their response to artificial drying. The two extremes are probably best represented by inbreds 140 and 143, and the data for both are included in Appendix Table I. Inbred 140 was most seriously affected by the artificial drying which greatly reduced the rag doll germination and the field emergence in the two high-moisture samples, while inbred 143 was only slightly affected by the artificial drying in these two samples, as compared with the low-moisture samples. Fig. 9 clearly illustrates the behaviour of the artificially-dried samples of these two inbreds in the field test.

While no actual measurements were taken to compare the rate of growth there was some indication that this was affected by artificial drying at the highest moisture levels in some inbreds but not in others. Inbred 141 in Fig. 9 shows a reduction in vigour and growth at the highest moisture content, while inbred 143 shows equal vigour and growth at all moisture levels. In Fig. 10 inbred 38 also shows the least growth at the highest moisture level. This reduction in growth and vigour may have been the result, to some extent at least, of retarded emergence.

Differential Response of Single- and Double-Cross Hybrids to Artificial Drying

Data have been presented to show that there were some differences in the reaction of inbred lines to artificial drying, when the ears were harvested in an immature condition. It became of interest to determine whether similar differences in response to drying existed in single- and double-cross hybrids.

In a test conducted with 26 corn hybrids ranging from 16 to 38 per cent moisture content at harvest, Kiesselbach(19) found no significant differential injury among them when they were dried at 112°F. for 5 days. He suggests the possibility that among hybrids differing greatly in moisture content at the time of drying, those

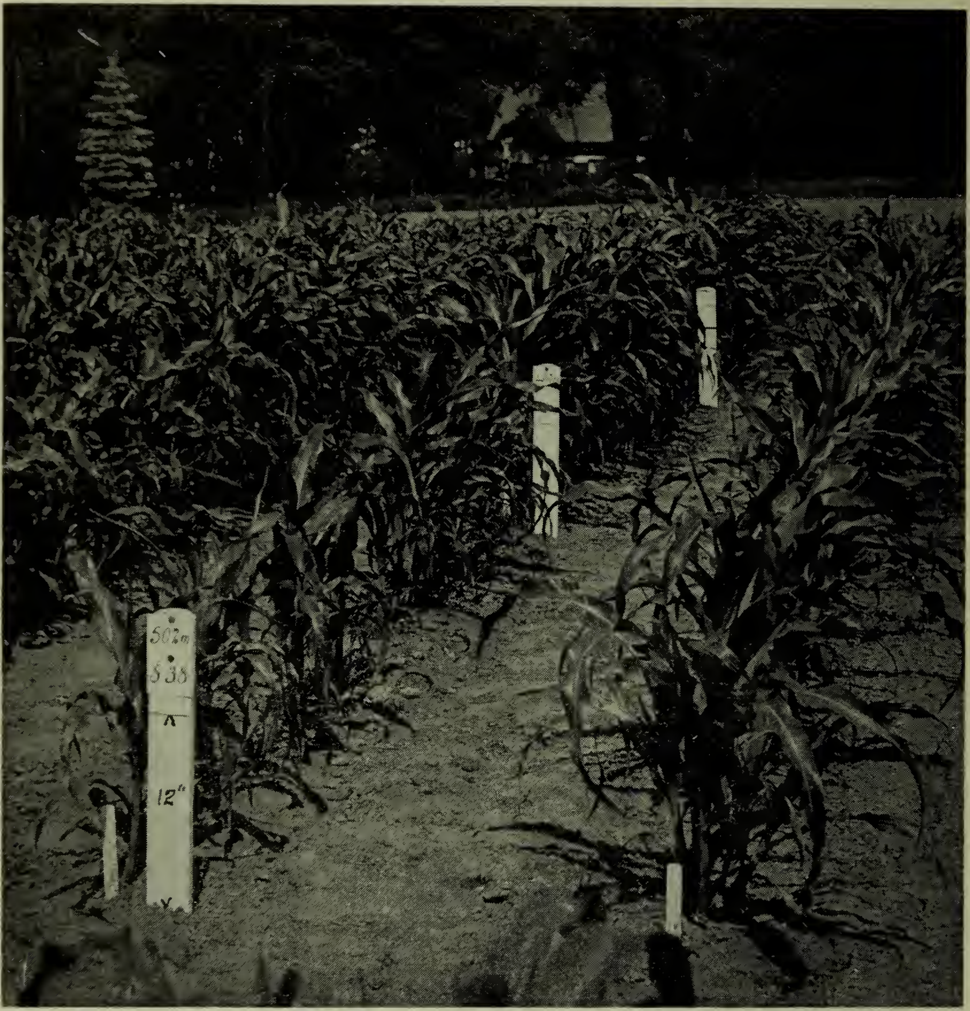


Fig. 10. Inbred 38. Showing differential response of inbreds to artificial drying of seed harvested at different maturities.

with excessive moisture would be injured and that this would not necessarily suggest heritable differences in heat susceptibility, but might be associated solely with moisture content. Differential resistance to leaf burning by hot, dry weather was found by Jenkins(15) in some inbred lines and their hybrid combinations, and the data which he obtained indicated that much might be accomplished by breeding corn for drought resistance. Instances of resistance to low temperatures in corn have been reported both as it affects germination and emergence in the spring (6) and as it affects the plant and the seed in the fall, Holbert and Burlison(13). Data obtained by Washko(31) in testing strains at comparable levels of moisture showed that with respect to heat injury, inbred lines were most susceptible, double-cross hybrids were most tolerant, and single-cross hybrids were intermediate in reaction. The data indicated that heat tolerance was not conditioned by simple genetic factors, but rather that it was related to the vigour of the respective strains.

Koehler, Dungan and Burlison(20) conducted a field test using seed which germinated 100 per cent from ears harvested at different stages of maturity and air dried. The field stands varied from 52.8 per cent for the milk stage to 91.4 per cent for the mature stage, and the yields from the milk stage were 32.2 per cent below those produced by the mature stage. Poor stands of the milk and late milk stages were unquestionably caused by poor vigour of the seedlings, many of which were unable to make their way through the ground. Mature seed gave the best all-round results. In a field test conducted by Kiesselbach(18), air-dried corn, harvested at 5 weekly intervals before ripe, yielded in no case more than 2 per cent less than fully matured seed. In a later study the same author(19) reported that seed corn containing 30 per cent of moisture at harvest and reduced to 5 per cent moisture in 5 days at 112°F. showed no unfavourable stand or seedling effects when planted in the field. Duncan and Marston(7) harvested corn in the milk, soft dough and hard dough condition and compared air-dried seed with seed artificially dried for 18 hours at 112°F. They found that the heat treated milk and soft dough corn gave lower germination than the comparable air-dried checks. Yields were correlated with stage of maturity as affected by the artificial drying, the lowest yields being produced by the milk stage seed, which was most affected by the drying process. They concluded that the earlier the stage of maturity and the higher the drying temperature the greater the loss in germination. Harrison and Wright(11) reported that seed corn dried to 12 per cent moisture or less in 72 to 96 hours at 104°F. to 113°F. was not injured in germination, seedling growth, or field performance. Seed corn harvested at different stages of maturity and air dried, was found by Robinson(25) to be equally productive when the stands were controlled and equal stands obtained. Where the stands were not controlled by thinning, the immature kernels, harvested in the dough stage, did not give as good stands as the mature kernels and consequently gave lower yields. Working with barley, Harlan(9) observed that adult plants were not so robust from the immature as from the mature seed.

The studies reported here comprised both germination and field tests. Ears of 32 single-cross and 32 double-cross hybrids were harvested at different dates to secure samples containing approximately 50, 40, 30 and 20 per cent of moisture in the kernels. Both the single and double crosses were combinations of inbreds included among the 36 lines already described. Ten ears were harvested at each of the moisture levels and the kernels were immediately sampled for determination of the moisture content. The average moisture contents obtained were as follows: single crosses, 49.6, 40.4, 29.0, and 20.1 per cent, and double crosses, 49.1, 41.2, 29.3 and 20.4 per cent respectively.

Immediately following the removal of the kernels for moisture determination the ears were broken into halves. Ten of the half-ears (alternate butts and tips) were air dried, while the remaining ten half-ears were artificially dried at 108°F. for 48 hours.

For the germination study one hundred kernels were taken at random from each of the air-dried and artificially-dried ear samples and tested by the rag doll method. The complete results, taken at the end of six days, are presented in Appendix Table 2. A summary of the data is shown in Table 18.

Germination was described as being either strong or weak according to the relative development of the sprouts within each individual sample. While this division may seem rather arbitrary, it was done in an attempt to distinguish between those which appeared to possess the necessary vitality and vigour to emerge successfully under field conditions and those which appeared as unlikely to do so. Some justification for this division was demonstrated in the field test of this material which is described later.

The summarized data in Table 18 show clearly that in comparison with the air-dried ears, artificial drying had little or no effect upon the germination of kernels taken from the single- and double-cross ear samples at the two lower levels of moisture, but had a very damaging effect upon the germination of those samples

TABLE 18—SUMMARY OF DATA OBTAINED FROM 32 SINGLE CROSSES AND 32 DOUBLE CROSSES, SHOWING AVERAGES FOR KERNEL MOISTURE CONTENT, AND RAG DOLL GERMINATION OF AIR-DRIED AND ARTIFICIALLY-DRIED KERNELS

Average moisture in kernels at harvest	Average germination					
	Air dried			Artificially dried, 108°F.		
	Strong	Weak	Total	Strong	Weak	Total
	%	%	%	%	%	%
Single crosses (32)						
49.6	91	4	95	18	18	36
40.4	95	3	98	56	16	72
29.0	96	2	98	90	5	95
20.1	98	1	99	96	2	98
Double crosses (32)						
49.1	91	6	97	36	22	58
41.2	93	5	98	71	18	89
29.3	96	3	99	93	6	99
20.4	97	2	99	94	4	98

harvested at the two higher levels of moisture, both by reducing the total percentage of germinated kernels and by increasing the percentage of kernels which produced weak sprouts. The single crosses suffered considerably more from the effects of artificial drying than the double crosses.

Individual hybrids of both single and double crosses showed a varied response to kernel moisture content and artificial drying. Some indication of this may be obtained from Table 19, which shows the percentage germination for both types of crosses at each moisture level.

TABLE 19—DISTRIBUTION OF 32 SINGLE CROSSES AND 32 DOUBLE CROSSES ACCORDING TO PERCENTAGE GERMINATION, AT EACH OF FOUR MOISTURE LEVELS

Average moisture in kernels at harvest	Air dried				Artificially dried, 108°F.						
	51-70%	71-80%	81-90%	91-100%	0-10%	11-30%	31-50%	51-70%	71-80%	81-90%	91-100%
%											
Single crosses (32)											
49.6......	0	2	5	25	10	5	7	6	2	1	1
40.4......		1	2	29		5	2	6	3	5	11
29.0......			1	31				1	1	1	29
20.1......				32						1	31
Double crosses (32)											
49.1......	1	1	1	29	4	6	2	6	2	4	8
41.2......		1	1	30		1	1	2	2	4	22
29.3......				32							32
20.4......				32							32

Considering the effects of maturity alone, as demonstrated by the air-dried samples, only 3 lots in both single and double crosses germinated less than 80 per cent, and these occurred within the samples at the two high moisture levels. Twenty-five of the single crosses and 29 of the double crosses germinated between 91 to 100 per cent at the highest level of moisture.

Of the artificially-dried samples, 48 single crosses and 26 double crosses germinated less than 80 per cent at the two high-moisture levels, while at the highest moisture level only one single cross and 8 double crosses germinated between 91 and 100 per cent.

No definite relationships can be shown between these results and those obtained from the inbred lines. As all of the seed for the tests was produced in the same year, nothing was known previously concerning the reactions of the inbred lines to stage of maturity at harvest and artificial drying. Had this information been available when the crosses were made, it is possible that inbreds could have been combined in such a manner as might have given some information on their breeding behaviour.

In the field test a study was made of the effects of maturity and artificial drying upon seedling emergence, stand and yield. Seed for this test was taken at random from the same half-ears as were used for the rag doll germination test. Only those hybrids were included in which the kernels from at least 5 of the 10 half-ears germinated 90 to 100 per cent strong on the rag doll, at each moisture level, both in the air-dried and artificially-dried samples. This limited the number tested to 8 hybrids, comprised of 3 single crosses and 5 double crosses. The variety Minnesota No. 13 was also included, making a total of 9 in all. The test was conducted for two years, 1941 and 1942, from seed which was produced in 1940.

Three replications were planted of each of the 9 lots and they were randomized in the individual replications. Each one was represented by 8 rows in each replication, 4 air dried and 4 artificially dried, and the rows were grown adjacent to one another. Single-row plots were used and a full stand consisted of 20 plants per plot in 1941 and 21 plants per plot in 1942. A single kernel was dropped every 12 inches in the rows and covered uniformly with a hand rake to a depth of about 1½ inches. The rows were spaced 3 feet apart.

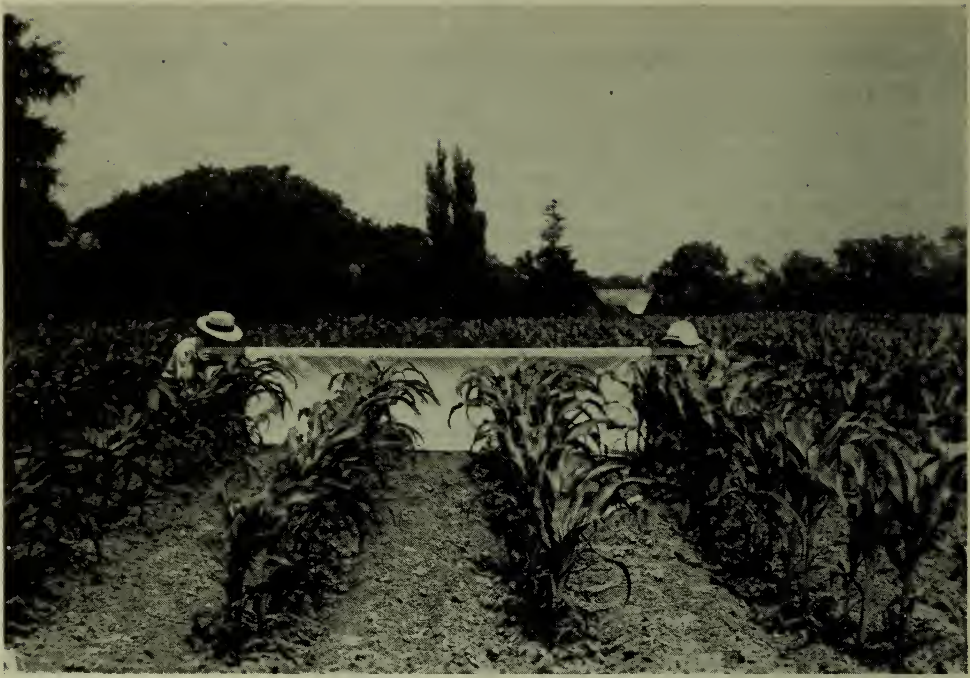
Detailed data with respect to seedling emergence and vigour and final stands are presented in Appendix Table 3, while yields in bushels per acre of shelled corn (absolute dry weight basis), together with statistical analyses of the data, are given in Appendix Table 4.

Conditions were generally more favourable in 1942 than in 1941 with respect to both season and soil. This influenced to some extent germination and seedling emergence and had a decided effect upon the yields obtained.

A summary of the data on seedling emergence and vigour, and final stands, included in Appendix Table 3, is given in Table 20.

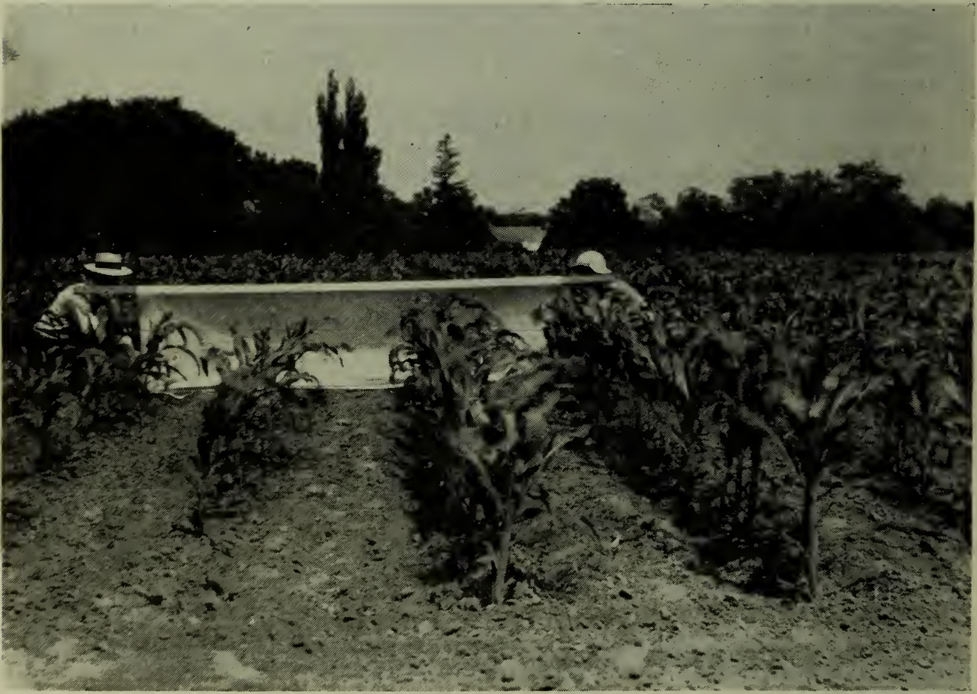
Although the seed for the field test was taken only from those ears which at all moisture levels germinated 90 to 100 per cent strong in the rag-doll tests, the data on seedling emergence and vigour presented in Table 20 show that the artificially-dried seed at the 48.9 and 41.2 moisture levels was seriously affected. Out of a total of 20 kernels per row planted in 1941, the average emergence was 51.7 per cent for the former and 71.6 per cent for the latter, resulting in final stands of 50 per cent and 70 per cent respectively. This compared with final stands of 93 per cent and 95 per cent respectively for the comparable air-dried lots. In 1942, emergence was 41.3 and 71.4 per cent from a total of 21 kernels per row planted, with final stands amounting to 38.1 per cent and 68.1 per cent respectively. The comparable air-dried samples produced final stands of 96.7 per cent. Figs. 11(a) and (b) show stands of corresponding air-dried and artificially-dried rows, (a) at early growth, and (b) at maximum growth. Both illustrations indicate somewhat greater vigour of growth with the advancing maturity of the planted kernels.

The poor stands produced by the artificially-dried samples at the 48.9 and 41.2 per cent moisture levels were all the more remarkable in view of the fact that the rag doll tests indicated just as high germination and as vigorous sprouts as at the other moisture levels, both air dried and artificially dried. A number of seeds were dug up and examined, and while germination had occurred in most cases the young sprouts apparently lacked the necessary vigour to penetrate and emerge from the



50 40 30 20

Untreated (Air dried)



50 40 30 20

Treated 108° F. 48 hrs.

Fig. 11. (a) Showing comparison of air-dried and artificially-dried hybrid at early growth stage. (50, 40, 30, 20 indicates approx. kernel moisture percentage at harvest)

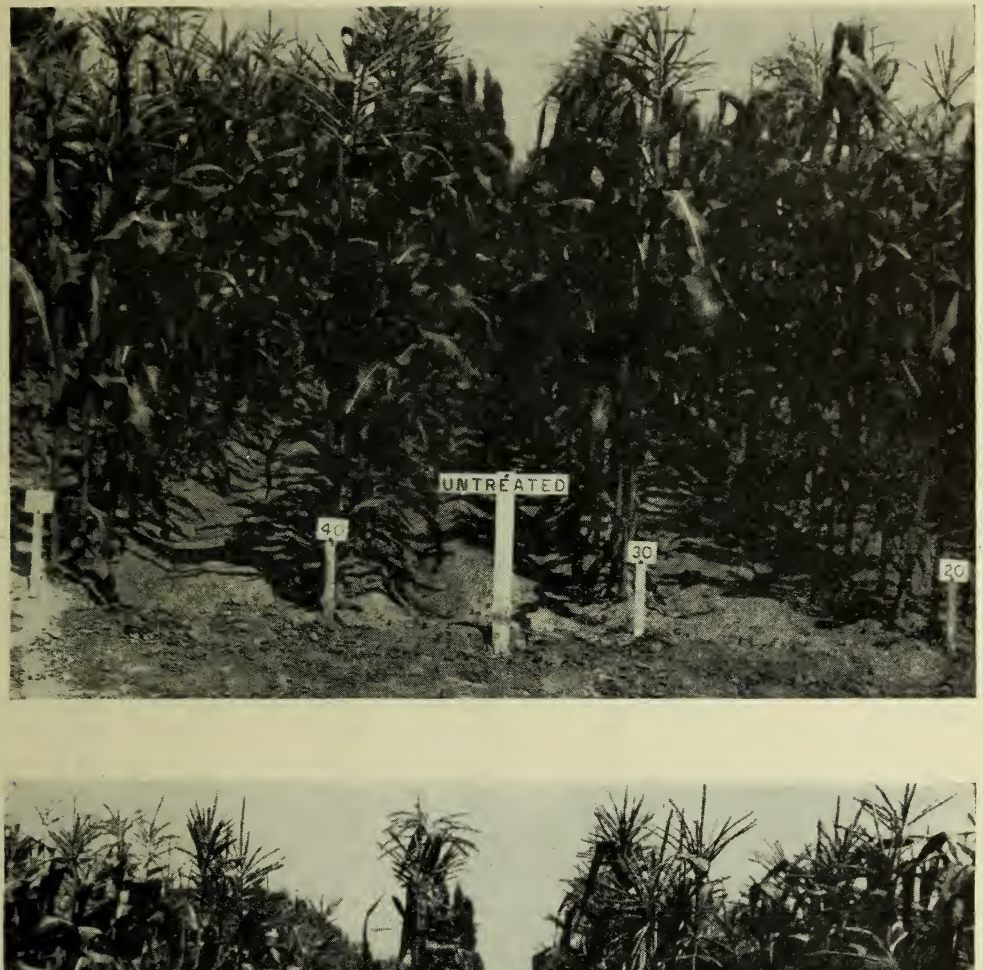


Fig. 11. (b) Showing comparison of air-dried and artificially-dried hybrid at maximum growth stage. (50, 40, 30, 20 indicates approx. kernel moisture percentage at harvest)

TABLE 20—SUMMARY OR AVERAGE OF THE FIELD DATA ON SEEDLING EMERGENCE AND VIGOUR, AND FINAL STAND FOR EIGHT HYBRIDS AND ONE VARIETY

Method of drying	Moisture in kernels at harvest	Seedling emergence			Final stand
		Total	Strong	Weak	
	%	%	%	%	%
1941					
Air dried	48.9	96.7	90.0	6.7	93.0
"	41.2	96.7	95.0	1.7	95.0
"	30.5	98.3	96.7	1.6	95.0
"	20.3	96.7	93.3	3.3	95.0
Artificially dried, 108°F	48.9	51.7	13.3	38.3	50.0
" "	41.2	71.6	45.0	26.7	70.0
" "	30.5	95.0	90.0	5.0	91.5
" "	20.3	96.7	93.3	3.3	95.0
1942					
Air dried	48.9	98.4	84.1	14.3	96.7
"	41.2	98.4	85.7	12.7	96.7
"	30.5	98.4	90.5	7.9	96.7
"	20.3	96.8	92.1	4.8	95.0
Artificially dried, 108°F	48.9	41.3	23.8	17.5	38.1
" "	41.2	71.4	50.8	20.6	68.1
" "	30.5	95.2	82.5	12.7	93.8
" "	20.3	96.8	90.5	6.3	96.7
Average 2 years, 1941–1942					
Air dried	48.9	97.6	87.1	11.5	94.9
"	41.2	97.6	90.4	7.2	95.9
"	30.5	98.4	93.6	4.8	95.9
"	20.3	96.8	92.7	4.1	95.0
Artificially dried, 108°F	48.9	46.5	18.6	27.9	44.1
" "	41.2	71.5	47.9	23.6	69.1
" "	30.5	95.1	86.3	8.8	92.7
" "	20.3	96.7	91.9	4.8	95.9

soil. Apparently the food reserves were not made available rapidly enough to sustain the young seedling until it reached the surface, and death ensued.

Emergence was extremely uniform and good at all moisture levels in the air-dried samples and the artificially-dried samples at the 30.5 and 20.3 per cent moisture levels. In all of these the final stands averaged over 90 per cent in both years.

Comparing emergence and stands for the two years the only difference worthy of note was that between the two artificially-dried 48.9 per cent moisture lots. The 1942 emergence was approximately two plants less per row than in 1941, resulting in a 12 per cent reduction in the final stand. As there was no similar difference between the comparable air-dried samples in the two years, it seems that the effect of artificially drying on the 48.9 per cent moisture sample might have been cumulative, becoming more damaging as the seed increased in age. The remaining samples did not show any noticeable differences between the behaviour of the artificially-dried and air-dried lots. In 1942, the final stand for the artificially-dried, 41.2 per cent moisture samples was only 1.9 per cent less than that of the air-dried samples. This difference might have been greater had not conditions in 1942 been more favourable for germination and emergence than in 1941.

There was considerable variation in the response of the individual hybrids to the effects of artificial drying. At the highest level of moisture, in no case was the emergence and final stand of any individual hybrid equal to that of the comparable air-dried lot. But whereas that of some hybrids was relatively high, that of others was relatively low. The behaviour was similar in both years and is well illustrated in Fig. 12.

The yields of shelled corn as presented in Appendix Table 4 are those obtained from the actual stands. No attempt was made to correct to a full stand as that would have defeated the purpose of the test. For the two years the average yields for the 8 hybrids and Minnesota No. 13 were as follows:—

AVERAGE YIELDS OF SHELLED CORN PER ACRE (DRY WEIGHT)

Method of drying	Moisture in kernels at harvest (%)			
	48.9	41.2	30.5	20.3
	bus.	bus.	bus.	bus.
		1941[1]		
Air dried	41.02	43.25	48.01	51.41
Artificially dried	26.52	38.44	45.35	47.83
		1942[1]		
Air dried	68.63	65.84	71.01	79.77
Artificially dried	31.99	57.82	74.91	72.58
	Average	2 years,	1941–1942	
Air dried	54.83	54.55	59.51	65.59
Artificially dried	29.26	48.14	60.13	60.21

[1] Necessary difference for significance between two average yields—

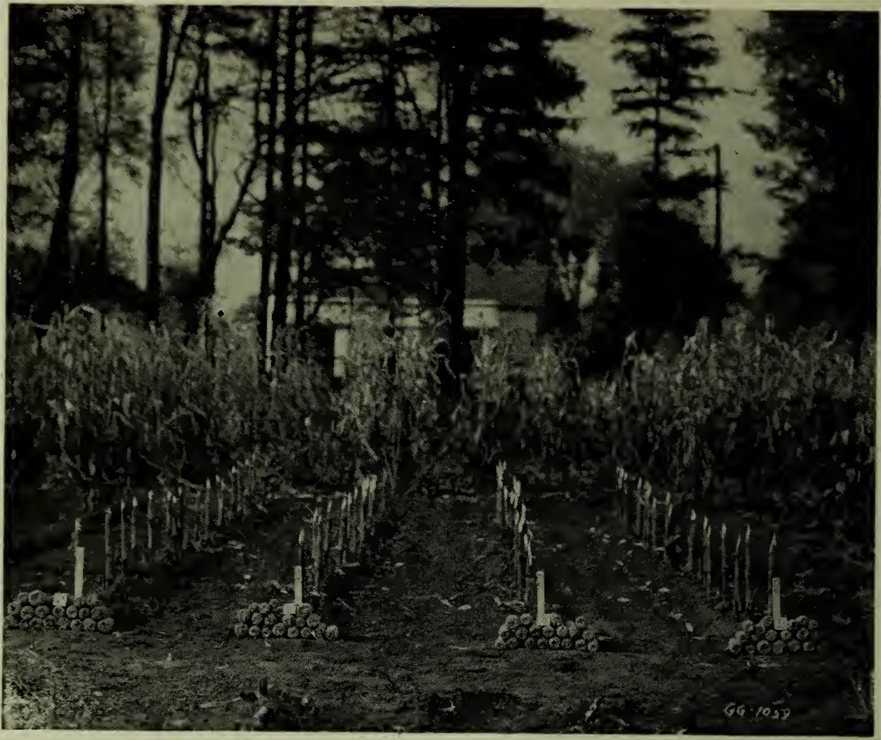
	P . . .05	P . . .01	
1941	6.11	8.03	bus. shelled corn per acre
1942	8.18	10.75	" "

The data presented in Table 20 show that the final stands of the air-dried samples were approximately the same, irrespective of the maturity of the ears at harvest. In no case did they differ by more than 2 per cent, in either of the two years. The average yields in both years, however, indicate that maturity had a definite effect upon production, as those obtained from the well-matured, 20.3 per cent moisture samples, were significantly higher than those obtained from the immature, 48.9 per cent samples.

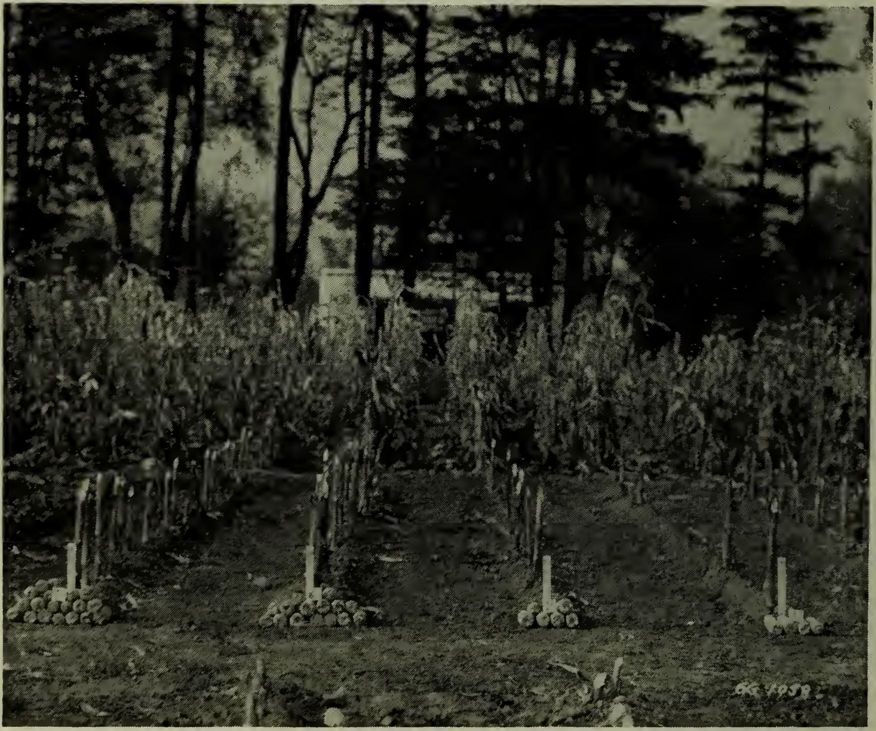
The yields of the artificially-dried samples were closely related to the final stands. The excellent stands of the mature 30.5 and 20.3 moisture samples resulted in the production of shelled corn yields that were significantly higher than those obtained from the immature, 48.9 and 41.2 per cent moisture samples.

In both 1941 and 1942, the air-dried samples were significantly higher in yield at all moisture levels than the artificially dried at the 48.9 per cent moisture level. Similarly, the yields of the mature, 30.5 and 20.3 per cent moisture samples were significantly higher than those of the artificially-dried samples at the 41.2 per cent moisture level. There were no significant differences between the yields of the corresponding air-dried and artificially-dried samples at the 30.5 and 20.3 per cent moisture levels.

Other interesting comparisons based upon statistical analyses of the data are shown in Appendix Table 4.



18.8%m. 32.0%m. (a) 44.2%m. 52.0%m.



18.8%m. 32.0%m. (b) 44.2%m. 52.0%m.

Fig. 12. Illustrating differential response of hybrids to artificial drying of seed harvested at different stages of maturity, as indicated by % moisture in kernels at harvest.

Hybrid 130 x 107—(a) air dried
(b) artificially dried, 108° F.

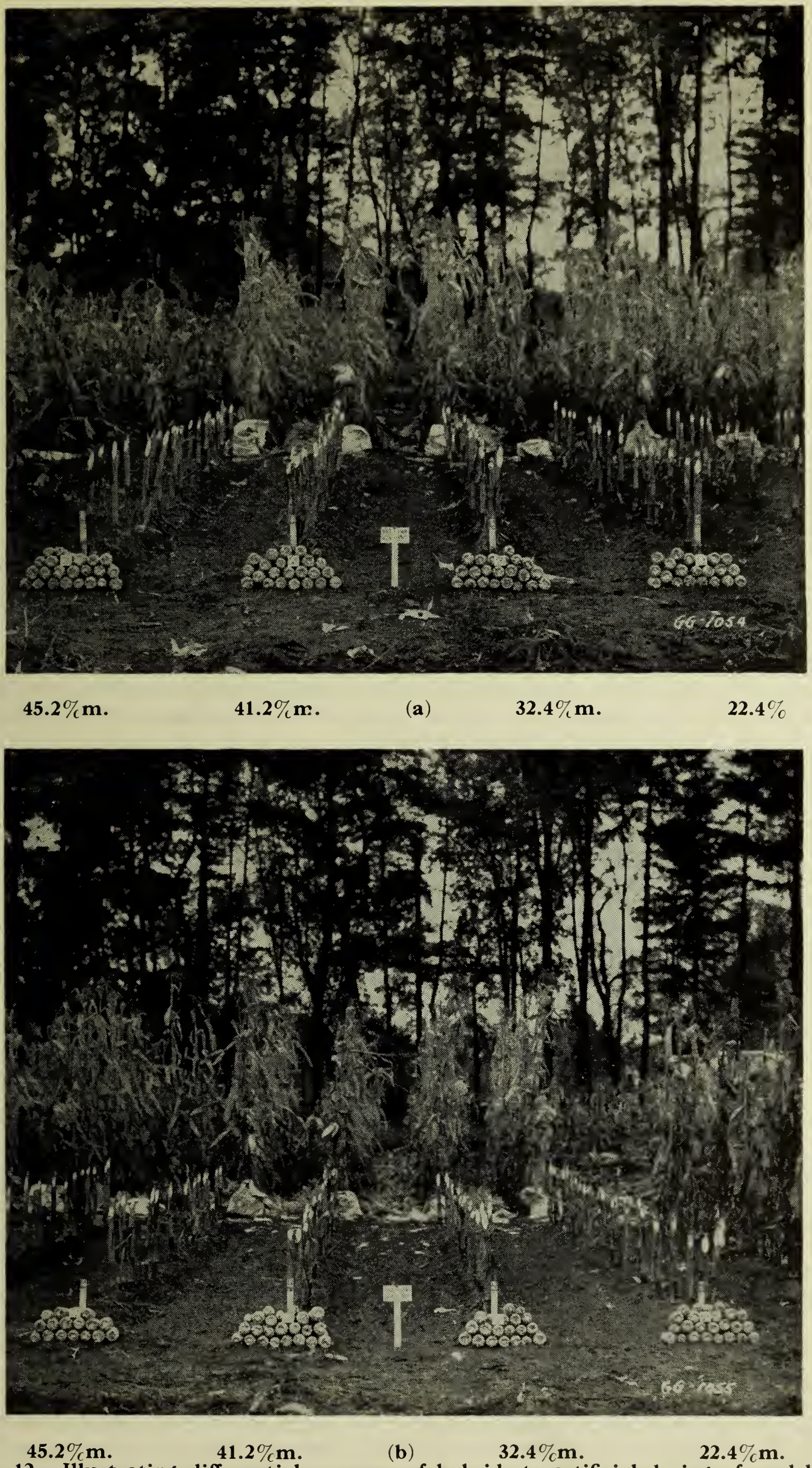


Fig. 12. Illustrating differential response of hybrids to artificial drying of seed harvested at different stages of maturity, as indicated by % moisture in kernels at harvest.

Hybrid (153 x 150) (148 x 151)—(a) air dried
(b) artificially dried, 108° F.

Discussion

The stage of maturity of the corn at harvest had a very definite effect upon its appearance as seed. Decided immaturity, as indicated by high kernel moisture content when husked, resulted in small, dull, wrinkled, unattractive seed, irrespective of method of drying. Maturity also profoundly affected the kernel weight, its volume and specific gravity, which decreased as moisture content increased. The composition of the seed as indicated by mechanical analyses showed that while the weight of all constituent parts decreased with immaturity, when related to kernel weight only the germ showed a decrease in percentage. Although the character of the endosperm changed in relation to maturity its total percentage remained approximately the same at all maturities. Chemical analyses, on the other hand, showed that the percentages of the various constituents remained essentially the same, irrespective of maturity, with the possible exception of the fat, which tended to decrease slightly with immaturity. Sprouting of the radicles was highest at the beginning in the immature kernels, but the plumules emerged most rapidly and with more apparent vigour and vitality in the mature samples. As was to be expected, therefore, seedling emergence occurred most quickly in the mature corn. Secondary roots developed more slowly in the immature, high-moisture samples, and also were fewer per kernel at the end of six days observation, than in the mature samples. Activity of the enzyme, diastase, was very low in the dry seeds, but was found to be highest in the air-dried immature samples. This was also true of the soaked seed which remained ungerminated at the end of three days, but in the germinated seeds diastase activity of the mature samples had reached the same level by the third day as that of the immature samples, and continued to be equally as high during the remainder of the observations.

Artificial drying at 108°F. accentuated most of the effects which resulted from immaturity in the air-dried corn. In comparison with air drying, its only noticeable effect upon the appearance of the kernels was to cause a somewhat greater degree of blistering or lifting of the pericarp and a bleaching of colour in the immature seed. While it had no effect upon the kernel weight, volume or specific gravity, and caused no appreciable changes in the composition of the kernels, it resulted in an increased imbibition of water and speeded up the sprouting of radicles in the immature samples to a greater degree than in the comparable air-dried samples. It retarded seedling emergence in all samples irrespective of maturity, and greatly reduced the total emergence of the two immature samples. Reduced diastatic action in all of the artificially-dried seed was probably caused by a partial destruction of the enzyme or by a general lowering of its activity. It seems probable that there was a significant relationship between the seedling emergence and diastatic activity of these samples, which was most marked in the most immature samples. As the food reserves in both the air-dried and artificially-dried kernels were essentially the same, the wide differences between them in seedling emergence must be attributed to some other cause, the most important of which was probably diastatic activity. Although many of the artificially-dried immature seeds germinated they did not emerge, presumably because the diastase activity was reduced to the extent that it was unable to make the food reserves available to the young seedlings rapidly enough to supply the necessary strength and vigour to enable them to push through to the surface of the soil before they succumbed.

The percentage imbibition of water was highest in the artificially-dried immature corn. As previously mentioned (p. 15) it was suggested by Robinson(25) that the greater attraction of a given unit of immature kernel for water might be greater porosity of the pericarp or the higher proportion of soft starch accompanied by a larger percentage of intergranular space. In addition to these possibilities the following hypotheses are advanced to explain the rapid absorption of water by the artificially-dried immature samples. First, less cutinization of the epidermis and second, a relatively high kernel sugar content, both brought about by the sudden arrest of the metabolic and maturation processes because of the rapid drying of the seed, which resulted in the reduction of the kernel moisture content to 14 per cent or lower in 48 hours. In comparison, the immature air-dried samples required several weeks to reach the 14 per cent moisture level, during which the rate of respiration would continue to be relatively high and the living processes within the seed proceed at an active although slowly diminishing rate as the moisture content became reduced. Assuming the suggested hypotheses to be correct, then the extent to which they would affect the rate of water absorption should depend largely upon the relative maturity of the samples at the time of drying. In other words, the more immature the corn, the less the cutinization of the epidermis and the higher the sugar content. The first of these would increase the porosity of the pericarp, while the second would exert its influence upon the absorption rate through its effect upon osmotic pressure within the cells. The results obtained give support to these hypotheses.

By using copper-constantan thermocouples it was found that heat penetrated the low-moisture ears most readily and the temperature in them rose higher and more rapidly than in the high-moisture ears. The results indicated that the greater evaporation from the high-moisture ears was effective in maintaining a lower and more uniform temperature of the kernels during the early stages of drying, but as drying continued and the moisture differences between the samples were lessened, the temperature readings showed less variation and became more nearly alike.

Drying at temperatures ranging from 130 to 150°F. for periods up to 24 hours proved injurious to the germination and seedling emergence of well-matured corn, which tested 22.5 per cent and 26.0 per cent of moisture at harvest. The corn was dried both shelled and on the ear, and it was found that the shelled corn suffered greater injury than the ear corn at all temperatures and at all periods of drying. The results of this experiment indicated little or no damage to corn containing 22.5 per cent of moisture at harvest and dried on the ear at 120°F.

The effects of artificial drying upon inbred lines, single-cross and double-cross hybrids, harvested at four stages of maturity, indicated a differential response to the heat treatment. Evidence was obtained which strongly suggested that among each of them there were individuals which were affected to a much greater or lesser extent than the average. Certain inbred lines appeared to be much less subject to damage by the drying process than others. The results indicate the possibility that by previously testing for response to artificial drying, inbreds might be selected and combined to produce hybrids that in seasons of poor maturity could be artificially dried at the temperatures ordinarily used with little or no injury to the germination of the seed.

In the two-year comparative-yield tests, which included eight air-dried and artificially-dried double and single crosses, together with the variety Minnesota No. 13, it was found that while the maturity of the seed at harvest had practically no effect upon the percentage emergence and stands obtained from the air-dried samples, it did nevertheless have a very profound effect upon the production capacity, as with very few exceptions the yields produced by the immature seed samples (48.9 and 41.2 per cent moisture) were considerably below those produced by the mature seed samples (30.5 and 20.3 per cent moisture). Comparison of the air-dried with the artificially-dried samples showed that while artificial drying had either little or no effect upon the stands or the yields obtained from the mature seed samples, its effect upon the immature seed samples was to greatly reduce the resulting stands and consequently the yields produced by nearly all of them.

In conclusion it may be stated as the result of these tests that seed corn harvested in a mature condition produced excellent stands and high yields, irrespective of whether it was air dried or artificially dried at 108°F. The only apparent effect of artificial drying was a slight retardation in the seedling emergence. Seed corn harvested in an immature condition and air dried, while slow in seedling emergence, produced excellent stands but was low in productive capacity. Artificial drying of immature seed at 108°F. resulted in poor stands brought about by low germination and poor seedling vigour, with consequent low yields.

These studies further suggest that the retardation of seedling emergence in the air-dried, immature seed, was probably due to low storage of reserve food materials in the seed and their exhaustion before the seedlings became well established, as diastatic activity was high in this seed. Low yield was the result of inferior plant performance caused by undernourishment in the early seedling stage, rather than poor stand. On the other hand, in the artificially-dried, immature seed, low yield was the result not only of low food reserves and its effect upon individual plant performance but chiefly of poor stands caused by poor germination and the inability of the seedlings to emerge from the soil. The studies on diastase suggest that both the failure to germinate and the poor emergence were probably the result of detrimental effects which artificial drying had upon this enzyme. It seems likely that in some seeds, the enzyme was either totally or almost totally destroyed. These seeds failed to germinate for lack of soluble food to nourish the embryo. In other seeds, the enzyme was either partially destroyed or its general activity lowered so that the amount of food made available to the developing embryo was insufficient to furnish the necessary vigour and vitality to enable the young seedlings to push through to the surface of the soil. Those seedlings which did manage to do so were mostly weak and spindly and slow to develop.

Summary and Conclusions

Ears of corn intended for seed use were harvested at different stages of maturity, and either artificially dried at 108 ± 1.5°F. or air dried.

Immaturity had definite effects upon the appearance of the seed. The kernels were small, shrunken, dull, opaque, and the pericarp often blistered. Artificial drying had no further effects upon such seed other than to cause some additional lifting or blistering of the pericarp and a rather bleached appearance.

Kernel weight, volume and specific gravity decreased with immaturity. Artificial drying brought about no appreciable change in these physical characters.

Imbibition of water was highest in amount in mature seed but highest in percentage in immature seed. Artificial drying resulted in an increase in the amount and the percentage imbibition in the immature seed.

In the early stages of germination radicles sprouted most quickly in the immature seed, while plumules and secondary roots developed most rapidly in the mature seed. Artificial drying speeded up the sprouting of radicles but greatly depressed the sprouting of plumules and the development of secondary roots in the immature seed.

Seedling emergence was most rapid in the mature seed. Immaturity retarded emergence while artificial drying caused a slight retardation of emergence in the mature seed and a greatly retarded and reduced total emergence of the immature seed.

Diastase activity was very low in the dry seed but was highest in the air-dried immature samples. In the germinated seed the activity of the diastase at the end of three days was as high in the mature as in the immature seed and continued equally as high for the remainder of the test period. Artificial drying had the effect of lowering diastase activity in all mature and immature seed samples during the entire observation period.

Mechanical analysis of the seed showed that the weight of the important constituent parts, including the pericarp, germ and endosperm, decreased with immaturity. Of the endosperm, the horny, translucent portion was greater in amount in the mature seed, while in the immature seed the soft, opaque portion became the more abundant of the two. Total endosperm was substantially the same in percentage in all samples irrespective of maturity or method of drying. Chemical analysis showed that irrespective of the maturity of the seed the percentages of the constituent parts, including ash, protein, nitrogen-free-extract, crude fibre and starch remained essentially the same, with the possible exception of the fat, which tended to decrease slightly with immaturity.

Mature seed containing 25.2 per cent and 35.1 of moisture, and immature seed containing 44.6 per cent of moisture, artificially dried for 32 days at 108 ± 1.5° F. was reduced to 2 per cent of moisture. The mature seed suffered no injury to the percentage germination but seedling emergence was increasingly retarded as the time of drying extended beyond 4 days, and the kernel moisture was reduced to below 4 per cent. The percentage germination of the immature seed decreased as the drying period increased, and seedling emergence was greatly retarded even after 2 days of drying, in comparison with the more mature seed.

According to thermocouple tests, temperatures of drying rose and fell more rapidly in mature kernels, while immature kernels maintained lower but more uniform temperatures. Average kernel temperatures during artificial drying were higher in mature corn than in immature corn. As drying continued and differences in moisture between the samples lessened, the temperatures showed less variation and became more uniform.

Well-matured corn, containing 22.5 per cent and 26.0 per cent of moisture at harvest, was dried at 110°F., 120°F., 130°F., 140°F., and 150°F., for periods up to 24 hours. The germination and seedling emergence were seriously affected at all temperatures above 120°F.

Inbred lines and single-cross and double-cross hybrids showed a differential response to artificial drying at 108 ± 1.5°F. While the seed of some was severely injured by artificial drying when harvested in an immature condition, that of others was only very slightly affected. The results obtained with the inbred lines suggest the possibility of combining inbreds which prove to be largely unaffected by the drying process to produce hybrids that could be dried without suffering serious damage to the germination, vigour and vitality of the seed, even when harvested in seasons unfavourable to the maturity of the seed crop.

Yields of single-cross and double-cross hybrids produced from seed harvested in an immature condition and air dried, were considerably below those obtained from mature seed in nearly all cases. Artificial drying of comparable seed resulted in reducing the stands of the immature samples and consequently the yields also, but the artificially-dried, mature seed produced equally as good stands and yields as the mature air-dried seed.

As the result of this investigation the drying of seed corn by heated air under forced draft, at a temperature 108 ± 1.5°F., can be recommended as a safe procedure for corn that has reached normal maturity, containing up to 35 per cent of moisture in the kernels at harvest. Such seed when dried on the ear to 14 per cent or slightly lower, suffers no injury to its germination, vitality or productivity, and may be shelled and stored safely. Seed dried to as low as 2 per cent of moisture suffers no reduction in germination, but seedling vigour is weakened and emergence retarded by such thorough drying, which is both costly and unnecessary.

Artificial drying at 108 ± 1.5°F. is injurious to immature corn in which the kernel moisture content exceeds 40 per cent at harvest. The effects of the drying process are to lower the percentage germination, retard seedling emergence and reduce seedling vigour. Productivity is reduced as the result of poor stands and inferior plant performance.

Seed containing an initial moisture content up to 22 per cent at harvest may be dried on the ear at 120 ± 1.5°F. for periods up to 24 hours without injury to its germination or reduction in percentage emergence, but seedling vigour may be slightly weakened.

Seed of inbred lines, single-cross and double-cross hybrids, artificially dried at 108 ± 1.5°F. may be expected to manifest a differential response to the drying process when harvested in an immature condition, with an initial kernel moisture content of 40 per cent or higher. In the case of inbreds this difference in response might well be given consideration in selecting lines for hybrid combination.

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APPENDIX TABLE 1

Rag doll germination and field emergence, 24 inbred lines, both air dried and artificially dried. (1)

Inbred	Moisture in kernels at harvest	Rag doll germination (after 6 days)						Field emergence (after 8 days)			
		Air Dried			Artificially Dried			Air Dried		Artificially Dried	
		Strong	Weak	Total	Strong	Weak	Total	8 days	Total	8 days	Total
		%	%	%	%	%	%	%	%	%	%
37	48.5	81	13	94	81	7	88	73	83	36	40
	41.3	80	12	92	81	9	90	80	90	70	76
	29.5	96	0	96	98	2	100	78	88	92	92
	20.0	97	1	98	98	2	100	83	93	90	92
38	50.0	97	1	98	90	8	98	70	88	48	54
	39.0	98	0	98	94	5	99	69	90	71	86
	29.8	100	0	100	90	10	100	90	95	94	98
	20.8	100	0	100	91	9	100	88	94	96	98
53	48.0	85	11	96	18	33	51	73	75	10	14
	42.0	94	6	100	90	7	97	76	82	78	84
	29.0	93	3	96	86	14	100	88	92	90	91
	19.2	92	8	100	91	7	98	88	91	89	93
54	50.1	83	9	92	82	9	91	82	82	28	42
	39.9	85	11	96	84	8	92	82	82	65	79
	31.0	88	8	96	84	8	92	85	88	72	82
	20.1	96	2	98	84	13	97	82	85	76	84
59	46.4	95	1	96	91	5	96	83	83	44	46
	39.2	99	1	100	98	0	98	92	97	86	92
	30.2	98	0	98	98	2	100	85	93	78	84
	21.0	96	2	98	97	2	99	83	85	82	88
113	51.5	53	25	78	43	43	86	45	45	24	33
	40.8	76	20	96	74	22	96	63	63	58	64
	30.1	96	4	100	92	7	99	90	92	86	91
	20.4	97	1	98	98	2	100	85	85	82	87
116	51.9	46	36	82	33	19	52	72	82	6	8
	41.1	72	20	92	60	28	88	85	85	72	74
	28.0	97	3	100	99	1	100	93	93	98	98
	20.2	96	4	100	98	2	100	93	93	97	98
122	50.1	72	16	88	30	59	89	84	85	52	54
	40.0	85	7	92	42	46	88	93	93	90	92
	31.6	98	0	98	65	25	90	90	90	92	92
	20.5	98	1	99	66	26	92	93	93	91	92
124	51.0	80	4	84	30	58	88	68	70	28	30
	40.0	90	2	92	94	5	99	85	85	88	88
	31.2	96	1	97	98	1	99	93	93	99	99
	20.2	98	0	98	98	2	100	95	95	98	99
125	45.6	44	31	75	38	36	74	58	58	36	42
	40.4	90	4	94	66	16	82	70	70	60	66
	28.0	99	1	100	98	0	98	88	88	78	80
	21.0	98	1	99	96	1	97	78	78	73	75
128	47.9	60	14	74	62	11	73	60	60	64	65
	40.0	65	16	81	60	27	87	68	75	52	58
	30.4	68	13	81	70	16	86	63	63	70	75
	21.0	70	14	84	71	13	84	65	65	66	68
129	50.3	56	18	74	49	20	69	60	60	58	60
	40.0	85	6	91	94	5	99	78	82	90	94
	27.0	86	7	93	98	1	99	78	80	82	90
	20.1	92	6	98	96	4	100	75	86	92	97
131	49.0	83	14	97	70	22	92	73	80	46	52
	40.4	92	4	96	98	1	99	85	85	87	95
	31.6	92	2	94	98	0	98	80	84	89	96
	21.2	93	5	98	96	2	98	88	88	90	95
134	49.4	49	45	94	42	51	93	60	63	64	70
	39.3	76	20	96	50	43	93	88	93	92	92
	28.0	80	16	96	51	37	88	85	88	88	89
	20.0	82	13	95	54	40	94	90	90	92	92
139	45.2	70	0	70	28	42	70	55	58	48	48
	39.2	81	16	97	32	41	73	58	62	48	60
	28.5	80	14	94	44	32	76	68	69	68	74
	20.5	82	17	99	34	42	76	85	85	74	79
140	51.8	39	43	82	1	2	3	70	75	2	4
	42.0	76	20	96	3	8	11	83	89	8	12
	29.6	66	29	95	64	32	96	91	93	86	92
	20.4	76	18	94	84	12	96	80	85	83	88
141	50.4	87	4	91	2	58	60	78	78	34	34
	40.0	90	2	92	35	53	88	90	93	82	86
	30.4	97	1	98	70	29	99	85	89	94	98
	20.1	96	3	99	99	1	100	83	88	94	97
143	49.6	88	8	96	88	8	96	90	93	90	96
	41.0	94	5	99	95	3	98	95	95	96	96
	28.5	94	6	100	97	2	99	88	94	96	98
	21.0	96	3	99	97	2	99	88	95	94	96
147	51.4	78	18	96	60	28	88	83	85	56	56
	38.5	98	1	99	64	26	90	83	85	75	88
	30.4	84	8	92	74	22	96	85	86	86	89
	18.2	97	3	100	88	11	99	85	90	85	90
148	49.4	91	7	98	46	38	84	80	80	16	22
	40.8	88	10	98	70	22	92	83	83	40	46
	29.0	92	4	96	94	3	97	83	85	88	89
	18.2	94	3	97	96	2	98	85	90	86	90
150	50.4	20	35	55	18	11	29	50	51	20	29
	39.8	56	29	85	18	15	33	75	85	26	30
	29.5	46	38	84	50	16	66	85	85	66	66
	20.8	62	23	85	47	18	65	88	88	72	77
151	50.0	91	6	97	88	10	98	65	91	66	88
	40.1	96	2	98	90	9	99	95	98	70	94
	30.9	94	2	96	94	4	98	90	94	86	96
	19.1	95	5	100	92	6	98	98	98	85	96
152	51.0	96	1	97	6	63	69	88	95	24	30
	38.8	97	2	99	41	55	96	95	99	84	95
	30.0	96	2	98	78	20	98	93	95	88	88
	21.0	94	5	99	96	2	98	88	93	91	92
153	49.2	88	10	98	62	31	93	58	75	44	58
	39.0	96	3	99	72	26	98	79	90	86	92
	29.2	92	4	96	76	22	98	73	85	86	90
	20.4	94	4	98	75	22	97	85	93	86	86

(1) Artificially dried, 108° F.

APPENDIX TABLE 2

Rag doll germination of 32 single crosses and 32 double crosses, both air dried and artificially dried. (1)

Single Cross	Moisture in kernels at harvest %	Germination					
		Air Dried			Artificially Dried		
		Strong %	Weak %	Total %	Strong %	Weak %	Total %
(38 x 37)	42.1	99	0	99	28	4	32
	38.7	94	5	99	95	3	98
	27.6	86	12	98	60	15	75
	18.4	94	6	100	93	4	97
(53 x 54)	48.9	98	0	98	0	39	39
	35.2	74	10	84	74	10	84
	30.8	91	8	99	83	8	91
	18.2	97	2	99	83	7	90
(114 x 113)	50.6	95	2	97	0	50	50
	43.6	100	0	100	11	69	80
	29.6	100	0	100	99	0	99
	21.6	100	0	100	99	0	99
(116 x 129)	49.8	86	4	90	44	21	65
	42.0	99	1	100	42	21	63
	28.4	100	0	100	93	2	95
	20.4	98	1	99	95	2	97
(125 x 117)	49.6	98	0	98	29	19	48
	41.6	99	0	99	32	9	41
	27.8	99	0	99	99	0	99
	19.2	100	0	100	100	0	100
(130 x 107)	52.0	87	5	92	46	32	78
	44.2	99	0	99	87	5	92
	32.0	98	0	98	92	1	93
	18.8	99	0	99	100	0	100
(130 x 128)	53.2	92	2	94	45	7	52
	44.3	93	3	96	83	1	84
	32.0	94	2	96	93	1	94
	21.6	100	0	100	100	0	100
(131 x 140)	54.6	100	0	100	12	28	40
	43.2	97	2	99	26	53	79
	30.2	100	0	100	99	1	100
	20.6	100	0	100	99	1	100
(134 x 125)	51.8	99	0	99	0	0	0
	37.6	88	12	100	1	18	19
	27.4	95	2	97	57	33	90
	20.4	97	2	99	95	3	98
(140 x 133)	48.0	99	0	99	0	3	3
	43.2	99	0	99	41	20	61
	26.4	98	0	98	97	0	97
	19.8	97	0	97	93	0	93
(144 x 122)	54.2	100	0	100	0	13	13
	37.4	100	0	100	99	0	99
	28.4	99	0	99	100	0	100
	22.4	98	0	98	98	2	100
(147 x 124)	53.6	85	2	87	0	2	2
	42.4	89	0	89	86	3	89
	26.0	95	2	97	93	3	96
	20.8	96	2	98	94	2	96
(151 x 150)	53.4	99	0	99	0	6	6
	39.2	100	0	100	100	0	100
	31.2	100	0	100	99	1	100
	21.2	99	1	100	98	1	99
(152 x 125)	46.1	99	0	99	2	28	30
	41.8	98	2	100	0	16	16
	29.2	99	1	100	99	1	100
	21.2	98	2	100	98	2	100
(152 x 140)	46.3	100	0	100	0	2	2
	40.6	100	0	100	10	18	28
	32.0	100	0	100	100	0	100
	20.4	99	1	100	98	2	100
(152 x 125)	46.0	97	0	97	0	20	20
	41.6	100	0	100	51	15	66
	26.2	100	0	100	100	0	100
	20.8	100	0	100	100	0	100
Double Cross							
(38 x 37)	42.8	86	14	100	14	51	65
(131 x 140)	36.0	74	26	100	45	55	100
	30.8	95	3	98	96	3	99
	20.8	92	6	98	88	11	99
(114 x 113)	48.0	85	12	97	27	56	83
(122 x 124)	42.8	98	2	100	86	14	100
	32.8	99	1	100	83	16	99
	20.0	100	0	100	99	1	100
(116 x 129)	49.1	100	0	100	98	1	99
(125 x 117)	39.0	97	0	97	100	0	100
	26.4	100	0	100	100	0	100
	21.0	96	0	96	99	0	99
(129 x 131)	49.2	96	4	100	81	17	98
(125 x 117)	40.0	100	0	100	88	8	96
	29.6	98	2	100	95	4	99
	21.6	99	0	99	93	3	96
(130 x 108)	52.4	59	30	89	6	20	26
(131 x 107)	42.6	49	38	87	9	30	39
	30.0	78	18	96	70	28	98
	20.6	84	12	96	82	16	98
(131 x 107)	48.0	100	0	100	96	2	98
(38 x 37)	40.4	99	0	99	100	0	100
	28.6	100	0	100	99	1	100
	20.4	100	0	100	100	0	100
(133 x 107)	48.5	70	27	97	51	43	94
(131 x 140)	43.0	71	28	99	54	42	96
	30.0	82	17	99	84	16	100
	17.4	90	10	100	75	25	100
(134 x 142)	52.0	35	27	62	4	20	24
(129 x 131)	41.2	87	10	97	3	24	27
	26.8	86	13	99	60	34	94
	18.4	83	9	92	86	12	98
(141 x 139)	50.8	100	0	100	3	26	29
(152 x 131)	38.8	99	0	99	93	4	97
	29.8	100	0	100	99	0	99
	21.4	95	4	99	99	0	99
(144 x 122)	54.2	98	2	100	2	17	19
(125 x 117)	42.6	100	0	100	99	1	100
	28.0	97	3	100	96	3	99
	20.4	99	0	99	98	1	99
(147 x 124)	52.8	76	4	80	4	10	14
(152 x 142)	42.0	80	0	80	74	3	77
	28.6	100	0	100	98	0	98
	18.6	99	0	99	97	2	99
(148 x 150)	45.2	98	0	98	91	8	99
(147 x 124)	36.8	99	1	100	100	0	100
	28.0	99	1	100	92	0	92
	22.0	98	1	99	97	2	99
(151 x 150)	46.8	98	1	99	98	0	98
(147 x 124)	42.0	99	1	100	100	0	100
	31.2	100	0	100	100	0	100
	20.8	100	0	100	99	1	100
(152 x 131)	48.8	98	1	99	17	63	80
(147 x 148)	41.8	98	1	99	41	49	90
	28.4	100	0	100	99	0	99
	21.8	99	0	99	99	0	99
(152 x 142)	49.6	96	4	100	4	29	33
(148 x 151)	43.6	99	0	99	11	41	52
	30.4	99	1	100	100	0	100
	22.0	99	0	99	97	3	100
(152 x 131)	48.8	94	2	96	82	8	90
(134 x 133)	43.6	95	4	99	85	14	99
	30.2	98	2	100	98	2	100
	21.6	99	1	100	87	11	98
Minn. No. 13	48.4	90	10	100	43	47	91
	38.4	95	5	100	76	21	97
	30.2	91	8	99	75	25	100
	21.0	98	2	100	92	8	100
(42 x 59)	41.8	100	0	100	45	9	54
	37.9	100	0	100	98	0	98
	26.0	98	1	99	100	0	100
	16.0	100	0	100	100	0	100
(83 x 85)	44.0	97	1	98	40	30	70
	37.3	93	2	95	80	5	85
	28.0	94	3	97	91	2	93
	18.2	92	3	95	91	4	95
(116 x 113)	50.4	94	1	95	8	51	59
	43.2	99	0	99	33	36	69
	30.4	95	0	95	93	1	94
	20.2	94	0	94	97	0	97
(122 x 124)	53.2	78	15	93	0	3	3
	38.0	88	10	98	17	26	43
	26.0	98	1	99	100	0	100
	20.0	99	0	99	98	1	99
(129 x 131)	52.8	56	25	81	0	4	4
	37.4	94	4	98	74	23	97
	28.8	92	1	93	91	4	95
	20.8	95	3	98	91	4	95
(130 x 108)	46.4	69	6	75	44	23	67
	39.4	99	0	99	82	7	89
	29.6	98	1	99	97	2	99
	19.2	97	0	97	97	0	97
(131 x 107)	46.4	77	9	86	15	33	48
	41.6	100	0	100	27	38	65
	29.4	100	0	100	100	0	100
	20.6	99	0	99	100	0	100
(133 x 107)	50.2	100	0	100	86	12	98
	42.2	100	0	100	99	1	100
	29.4	99	0	99	100	0	100
	16.4	99	0	99	99	0	99
(134 x 133)	50.2	61	26	87	0	0	0
	40.0	51	41	92	0	22	22
	27.0	54	35	89	50	46	96
	18.2	87	5	92	84	7	91
(141 x 139)	52.4	79	7	86	0	11	11
	42.0	95	3	98	14	48	62
	27.0	96	0	96	94	1	95
	21.6	95	3	98	95	4	99
(144 x 143)	54.2	73	5	78	0	0	0
	43.2	73	3	76	73	4	77
	31.6	98	2	100	96	2	98
	19.8	95	3	98	91	5	96
(147 x 148)	55.4	99	1	100	2	3	5
	40.8	100	0	100	94	4	98
	31.0	94	5	99	92	5	97
	21.2	98	2	100	94	4	98
(151 x 153)	49.2	98	1	99	60	29	89
	39.2	100	0	100	94	5	99
	31.4	98	2	100	96	4	100
	22.8	98	1	99	97	1	98
(152 x 131)	46.4	100	0	100	9	36	45
	35.1	99	0	99	75	16	91
	29.2	99	1	100	96	2	98
	21.6	99	0	99	97	2	99
(153 x 129)	47.6	91	2	93	35	40	75
	37.6	98	1	99	97	2	99
	29.6	99	1	100	97	2	99
	20.6	98	2	100	96	3	99
(152 x 131)	46.3	97	0	97	4	18	22
	40.4	99	1	100	0	22	22
	28.4	98	2	100	30	24	54
	20.8	97	2	99	95	5	100
Double Cross							
(53 x 54)	44.5	97	2	99	73	6	79
(42 x 59)	37.6	97	1	98	83	3	86
	28.4	100	0	100	100	0	100
	17.0	99	0	99	97	2	99
(116 x 113)	48.8	99	0	99	88	5	93
(125 x 117)	41.6	100	0	100	88	3	91
	30.8	98	2	100	99	1	100
	18.0	99	0	99	100	0	100
(125 x 117)	50.0	86	13	99	63	19	82
(122 x 124)	42.6	80	19	99	81	18	99
	30.8	84	16	100	85	14	99
	22.6	97	3	100	88	8	96
(130 x 107)	48.1	95	3	98	43	12	55
(116 x 113)	42.0	91	7	98	90	7	97
	28.0	98	0	98	100	0	100
	21.8	98	0	98	97	0	97
(130 x 128)	48.3	78	18	96	6	50	56
(156 x 142)	41.0	95	5	100	31	53	84
	30.8	77	19	97	72	27	99
	20.4	97	3	100	96	3	99
(131 x 140)	50.4	100	0	100	50	18	68
(114 x 113)	43.2	100	0	100	83	14	97
	29.6	100	0	100	100	0	100
	20.0	96	0	96	94	0	94
(134 x 133)	50.	99	0	99	25	48	73
(125 x 117)	43.6	97	2	99	33	33	66
	26.0	99	0	99	98	0	98
	20.8	97	0	97	98	0	98
(140 x 133)	50.1	98	1	99	9	61	70
(125 x 117)	43.2	98	0	98	99	0	99
	30.0	100	0	100	100	0	100
	18.8	96	0	96	94	0	94
(143 x 153)	52.8	96	2	98	0	0	0
(148 x 151)	42.0	95	5	100	67	33	100
	28.6	98	1	99	98	2	100
	18.6	98	1	99	99	0	99
(144 x 143)	52.4	94	5	99	0	0	0
(152 x 140)	42.4	96	2	98	74	15	89
	30.0	100	0	100	100	0	100
	18.4	98	2	100	98	1	99
(147 x 148)	49.2	99	1	100	12	18	30
(141 x 139)	38.0	100	0	100	62	36	98
	27.6	100	0	100	72	27	99
	18.6	99	1	100	80	18	98
(148 x 151)	48.2	98	1	99	1	5	6
(147 x 124)	41.6	100	0	100	100	0	100
	28.0	100	0	100	100	0	100
	22.4	99	1	100	99	0	99
(151 x 153)	46.4	98	1	99	1	1	2
(152 x 142)	41.2	97	2	99	98	2	100
	30.0	100	0	100	99	0	99
	20.8	100	0	100	98	2	100
(152 x 140)	49.6	99	1	100	5	30	35
(125 x 117)	39.0	97	2	99	71	23	94
	30.0	98	1	99	83	12	95
	22.0	99	0	99	88	8	96
(153 x 150)	45.2	98	1	99	85	14	99
(148 x 151)	41.2	99	0	99	97	1	98
	32.4	08	0	08	94	0	94
	22.4	98	1	99	97	1	98
(152 x 142)	50.0	91	8	99	10	50	60
(129 x 131)	41.2	90	10	100	25	46	71
	27.2	94	6	100	90	10	100
	20.8	96	3	99	91	9	100

(1) Artificially dried, 108° F.)

APPENDIX TABLE 3

Effect of maturity of seed and artificial drying (1) upon seedling emergence and vigour, and final stand of 8 hybrids and 1 variety

Hybrid or Variety	Method of Drying	Moisture in kernels at harvest %	1941						
			Seedling Emergence				Final Stand		
			Total	Strong	Weak	Ave. per row	Total Plants	Ave. per row	Percent
(153 x 150) (148 x 151)	Air Dried	45.2	59	58	1	19.7	58	19.3	96.5
	“	41.2	58	58	0	19.3	58	19.3	96.5
“	“	32.4	60	58	2	20.0	59	19.7	98.5
“	“	22.4	47	47	0	15.7	46	15.3	76.5
“	Artificially Dried	45.2	41	18	23	13.7	41	13.7	68.5
“	“	41.2	55	46	9	18.3	55	18.3	91.5
“	“	32.4	59	56	3	19.7	58	19.3	96.5
“	“	22.4	47	42	5	15.7	47	15.7	78.5
(116 x 113) (125 x 117)	Air Dried	48.8	60	57	3	20.0	59	19.7	98.5
	“	41.6	59	58	1	19.7	58	19.3	96.5
“	“	30.8	60	60	0	20.0	57	19.0	95.0
“	“	18.0	60	59	1	20.0	59	19.7	98.5
“	Artificially Dried	48.8	28	19	9	9.3	28	9.3	46.5
“	“	41.6	39	12	27	13.0	38	12.7	63.5
“	“	30.8	60	60	0	20.0	57	19.0	95.0
“	“	18.0	59	58	1	19.7	59	19.7	98.5
(131 x 107) (38 x 37)	Air Dried	48.0	58	58	0	19.3	54	18.0	90.0
	“	40.4	59	58	1	19.7	58	19.3	96.5
“	“	28.6	60	56	4	20.0	56	18.7	93.5
“	“	20.4	60	60	0	20.0	56	18.7	93.5
“	Artificially Dried	48.0	50	25	25	16.7	44	14.7	73.5
“	“	40.4	54	46	8	18.0	49	16.3	81.5
“	“	28.6	60	54	6	20.0	58	19.3	96.5
“	“	20.4	60	60	0	20.0	56	18.7	93.5
(129 x 131) (125 x 117)	Air Dried	49.2	59	55	4	19.7	57	19.0	95.0
	“	40.0	60	57	3	20.0	56	18.7	93.5
“	“	29.6	58	56	2	19.3	58	19.3	96.5
“	“	21.6	58	55	3	19.3	58	19.3	96.5
“	Artificially Dried	49.2	13	0	13	4.3	12	4.0	20.0
“	“	40.0	40	25	15	13.3	40	13.3	66.5
“	“	29.6	57	55	2	19.0	54	18.0	90.0
“	“	21.6	59	59	0	19.7	58	19.3	96.5
(152 x 131) (134 x 133)	Air Dried	48.8	58	58	0	19.3	58	19.3	96.5
	“	43.6	58	58	0	19.3	58	19.3	96.5
“	“	30.2	60	59	1	20.0	59	19.7	98.5
“	“	21.6	60	60	0	20.0	58	19.3	96.5
“	Artificially Dried	48.8	22	0	22	7.3	22	7.3	36.5
“	“	43.6	47	28	19	15.7	47	15.7	78.5
“	“	30.2	58	50	8	19.3	57	19.0	95.0
“	“	21.6	60	59	1	20.0	58	19.3	96.5
(133 x 107)	Air Dried	50.2	58	43	15	19.3	55	18.3	91.5
“	“	42.2	59	59	0	19.7	55	18.3	91.5
“	“	29.4	60	58	2	20.0	53	17.7	88.5
“	“	16.4	60	59	1	20.0	57	19.0	95.0
“	Artificially Dried	50.2	39	6	33	13.0	35	11.7	58.5
“	“	42.2	38	10	28	12.7	35	11.7	58.5
“	“	29.4	57	56	1	19.0	53	17.7	88.5
“	“	16.4	60	59	1	20.0	54	18.0	95.0
(151 x 153)	Air Dried	49.2	60	56	4	20.0	59	19.7	98.5
“	“	39.2	58	57	1	19.3	58	19.3	96.5
“	“	31.4	59	58	1	19.7	58	19.3	96.5
“	“	22.8	59	49	10	19.7	58	19.3	96.5
“	Artificially Dried	49.2	33	10	23	11.0	33	11.0	55.0
“	“	39.2	58	53	5	19.3	58	19.3	96.5
“	“	31.4	60	59	1	20.0	58	19.3	96.5
“	“	22.8	60	57	3	20.0	58	19.3	96.5
(130 x 107)	Air Dried	52.0	52	41	11	17.3	49	16.3	86.5
“	“	44.2	58	54	4	19.3	56	18.7	93.5
“	“	32.0	57	56	1	19.0	56	18.7	93.5
“	“	18.8	59	54	5	19.7	59	19.7	98.5
“	Artificially Dried	52.0	19	0	19	6.3	19	6.3	31.5
“	“	44.2	39	11	28	13.0	38	12.7	63.5
“	“	32.0	49	46	3	16.3	48	16.0	80.0
“	“	18.8	60	60	0	20.0	60	20.0	100.0
Minn. No. 13	Air Dried	48.4	59	58	1	19.7	58	19.3	96.5
“	“	38.4	58	57	1	19.3	58	19.3	96.5
“	“	30.2	59	58	1	19.7	59	19.7	98.5
“	“	21.0	59	59	0	19.7	59	19.7	98.5
“	Artificially Dried	48.4	27	4	23	9.0	27	9.0	45.0
“	“	38.4	26	5	21	8.7	26	8.7	43.5
“	“	30.2	49	49	0	16.3	48	16.0	80.0
“	“	21.0	59	55	4	19.7	59	19.7	98.5
						1942			
(153 x 150) (148 x 151)	Air Dried	45.2	62	60	2	20.7	61	20.3	96.7
	“	41.2	60	57	3	20.0	59	19.7	93.8
“	“	32.4	61	60	1	20.3	60	20.0	95.2
“	“	22.4	54	54	0	18.0	53	17.7	84.3
“	Artificially Dried	45.2	48	32	16	16.0	46	15.3	72.9
“	“	41.2	61	54	7	20.2	59	19.7	93.8
“	“	32.4	63	58	5	21.0	61	20.3	96.7
“	“	22.4	58	56	2	19.3	58	19.3	91.9
(116 x 113) (125 x 117)	Air Dried	48.8	62	57	5	20.7	62	20.7	98.6
	“	41.6	63	58	5	21.0	63	21.0	100.0
“	“	30.8	63	62	1	21.0	63	21.0	100.0
“	“	18.0	62	61	1	20.7	62	20.7	98.6
“	Artificially Dried	48.8	25	16	9	8.3	24	8.0	38.1
“	“	41.6	44	28	16	14.7	43	14.3	68.1
“	“	30.8	62	60	2	20.7	62	20.7	98.6
“	“	18.0	63	60	3	21.0	62	20.7	98.6
(131 x 107) (38 x 37)	Air Dried	48.0	63	57	6	21.0	62	20.7	98.6
	“	40.4	63	58	5	21.0	62	20.7	98.6
“	“	28.6	63	56	7	21.0	62	20.7	98.6
“	“	20.4	63	58	5	21.0	61	20.3	96.7
“	Artificially Dried	48.0	51	35	16	17.0	48	16.0	76.2
“	“	40.4	62	50	12	20.7	57	19.0	90.5
“	“	28.6	63	53	10	21.0	61	20.3	96.7
“	“	20.4	62	58	4	20.7	61	20.3	96.7
(129 x 131) (125 x 117)	Air Dried	49.2	63	59	4	21.0	62	20.7	98.6
	“	40.0	63	60	3	21.0	63	21.0	100.0
“	“	29.6	62	57	5	20.7	62	20.7	98.6
“	“	21.6	62	61	1	20.7	62	20.7	98.6
“	Artificially Dried	49.2	7	2	5	2.3	5	1.7	8.1
“	“	40.0	44	25	19	14.7	43	14.3	68.1
“	“	29.6	63	54	9	21.0	62	20.7	98.6
“	“	21.6	62	56	6	20.7	62	20.7	98.6
(152 x 131) (134 x 133)	Air Dried	48.8	62	51	11	20.7	62	20.7	98.6
	“	43.6	63	50	13	21.0	61	20.3	96.7
“	“	30.2	62	55	7	20.7	62	20.7	98.6
“	“	21.6	62	59	3	20.7	62	20.7	98.6
“	Artificially Dried	48.8	19	9	10	6.3	13	4.3	20.5
“	“	43.6	46	34	12	15.3	40	13.3	63.3
“	“	30.2	61	55	6	20.3	61	20.3	96.7
“	“	21.6	62	57	5	20.7	60	20.0	95.2
(133 x 107)	Air Dried	50.2	62	49	13	20.7	60	20.0	95.2
“	“	42.2	58	51	7	19.3	56	18.7	89.0
“	“	29.4	60	54	6	20.0	60	20.0	95.2
“	“	16.4	62	56	6	20.7	59	19.7	93.8
“	Artificially Dried	50.2	37	19	18	12.3	37	12.3	58.6
“	“	42.2	38	25	13	12.7	38	12.7	60.5
“	“	29.4	60	44	16	20.0	59	19.7	93.8
“	“	16.4	63	50	13	21.0	63	21.0	100.0
(151 x 153)	Air Dried	49.2	62	56	6	20.7	61	20.3	96.7
“	“	39.2	63	54	9	21.0	61	20.3	96.7
“	“	31.4	62	57	5	20.7	62	20.7	98.6
“	“	22.8	60	58	2	20.0	60	20.0	95.2
“	Artificially Dried	49.2	28	13	15	9.3	27	9.0	42.9
“	“	39.2	62	52	10	20.7	62	20.7	98.6
“	“	31.4	63	53	10	21.0	63	21.0	100.0
“	“	22.8	61	60	1	20.3	61	20.3	96.7
(130 x 107)	Air Dried	52.0	56	32	24	18.7	56	18.7	89.0
“	“	44.2	61	47	14	20.3	61	20.3	96.7
“	“	32.0	61	55	6	20.3	57	19.0	90.5
“	“	18.8	59	57	2	19.7	59	19.7	93.8
“	Artificially Dried	52.0	7	3	4	2.3	7	2.3	11.0
“	“	44.2	27	13	14	9.0	27	9.0	42.9
“	“	31.4	46	36	10	15.3	46	15.3	72.9
“	“	18.8	59	56	3	19.7	58	19.3	91.9
Minn. No. 13	Air Dried	48.4	62	53	9	20.7	62	20.7	98.6
“	“	38.4	63	55	8	21.0	63	21.0	100.0
“	“	30.2	63	59	4	21.0	63	21.0	100.0
“	“	21.0	63	60	3	21.0	61	20.3	96.7
“	Artificially Dried	48.4	8	1	7	2.7	8	2.7	12.9
“	“	38.4	21	9	12	7.0	21	7.0	33.3
“	“	30.2	61	56	5	20.3	59	19.7	93.8
“	“	21.0	63	58	5	21.0	62	20.7	98.6

(1) Artificial drying, 108° F.

APPENDIX TABLE 4

Effect of maturity of seed and artificial drying upon the yields of single- and double-cross hybrids

1941.—Yields in bushels of shelled corn per acre (absolute dry weight)

Hybrid or Variety	Average kernel moisture at harvest (%)											
	48.9	*41.2*	*30.5*	*20.3*	*48.9*	*41.2*	*30.5*	*20.3*	*48.9*	*41.2*	*30.5*	*20.3*
	Replicate 1				Replicate 2				Replicate 3			
	bus.	bus.	bus.	bus.	bus.	bus.	bus.	bus.	bus.	bus.	bus.	bus.
	AIR DRIED											
(153 x 150) (148 x 151)	32.20	29.30	36.39	33.60	41.29	51.66	58.04	57.05	41.28	42.67	56.22	50.75
(116 x 113) (125 x 117)	30.66	19.87	21.44	20.09	40.70	43.79	45.49	55.66	45.40	53.15	58.15	57.73
(131 x 107) (38 x 37)	42.71	62.87	62.34	57.44	44.82	44.41	46.53	41.08	41.99	52.62	57.67	45.23
(129 x 131) (125 x 117)	27.65	38.86	39.74	39.09	30.34	38.24	28.95	52.59	28.30	36.18	36.39	65.44
(152 x 131) (134 x 133)	60.02	57.73	67.38	62.18	56.75	47.09	53.89	50.84	25.34	19.25	46.46	63.01
(133 x 107)	57.02	56.54	53.52	57.52	23.34	23.11	36.32	45.48	34.53	40.50	29.03	39.86
(151 x 153)	36.46	28.80	33.32	39.65	60.13	62.02	58.48	43.32	64.63	64.54	69.73	62.54
(130 x 107)	34.08	41.29	47.32	65.85	34.07	47.27	49.34	59.84	34.29	47.26	48.73	60.52
Minnesota No. 13	58.28	44.46	60.84	53.46	40.97	38.43	43.96	48.18	40.38	35.72	50.66	60.02
	Artificially Dried, 108° F.											
(153 x 150) (148 x 151)	30.98	30.98	35.35	25.00	30.29	63.80	61.11	58.11	42.64	38.73	45.66	43.71
(116 x 113) (125 x 117)	19.30	15.18	21.00	14.22	19.93	35.16	51.14	49.54	19.94	29.85	64.90	68.06
(131 x 107) (38 x 37)	28.77	43.14	41.18	47.92	30.20	37.75	38.43	37.29	31.62	27.60	27.48	29.55
(129 x 131) (125 x 117)	No plts.	17.97	25.67	46.39	20.32	43.43	35.86	44.32	15.54	49.42	46.01	48.35
(152 x 131) (134 x 133)	8.52	51.80	57.24	51.77	28.93	43.03	38.16	42.52	38.08	45.04	60.60	59.10
(133 x 107)	41.36	48.68	51.27	51.71	23.29	28.98	38.86	41.38	37.03	24.34	35.07	41.70
(151 x 153)	31.21	40.02	48.08	53.90	23.39	52.12	56.50	53.91	39.64	74.44	70.58	75.06
(130 x 107)	18.49	41.45	39.97	51.29	22.39	45.09	43.91	43.93	19.76	35.64	47.95	50.05
Minnesota No. 13	36.24	39.63	52.08	55.81	27.25	21.00	50.11	66.43	31.19	13.75	40.31	40.44

ANALYSIS OF VARIANCE

	Due to	S S	D F	M.S	F	F value for 5%	F value for 1%
	Methods of Treatment	2200.0798	1	2200.0798	16.78	3.89	6.76
	% Moisture at Harvest	7927.3375	3	2642.4455	20.15	2.65	3.88
	Varieties	4529.2822	8	566.1603	4.32	1.98	2.60
(A)	Replicates	594.3907	2	297.1954	2.28	3.04	4.71
	Error (1)	26356.1577	201	131.1252			
	Interaction method x moisture	1215.2182	3	405.0727	6.14	2.67	3.91
	" method x varieties	923.1851	8	115.3981	1.75	2.00	2.62
	" moisture x varieties	3155.3643	24	131.4735	1.99	1.59	1.91
	" methods x replicates	92.4600	2	46.2330	1.43	19.49	99.49
(B)	" moisture x replicates	313.9173	6	52.3196	1.26	3.70	6.97
	" varieties x replicates	11283.2609	16	705.2038	10.68	1.71	2.12
	Error (2)	9372.7459	142	66.0053			

1941.—Mean yields in bushels of shelled corn per acre (absolute dry weight)

Hybrid or Variety	Air Dried				Artificially Dried				Air Dried and Artificially Dried				Air Dried	Artificially Dried	General Mean
	Average kernel moisture at harvest (%)												All Moistures		
	48.9	*41.2*	*30.5*	*20.3*	*48.9*	*41.2*	*30.5*	*20.3*	*48.9*	*41.2*	*30.5*	*20.3*			
(153 x 150) (148 x 151)	38.26	41.21	50.22	47.13	34.64	44.50	47.37	42.27	36.45	42.86	48.80	44.70	44.20	42.20	43.20
(116 x 113) (125 x 117)	38.92	38.94	41.69	44.49	19.72	26.73	45.68	43.94	29.32	32.83	43.69	44.22	41.01	34.02	37.51
(131 x 107) (38 x 37)	43.17	53.30	55.51	47.92	30.16	36.16	35.70	38.25	36.69	44.73	45.61	43.09	49.98	35.08	42.53
(129 x 131) (125 x 117)	28.76	37.76	35.03	52.37	11.95	36.94	35.85	46.36	20.36	37.35	35.44	49.37	38.48	32.77	35.63
(152 x 131) (134 x 133)	47.37	41.36	55.91	58.68	25.18	46.62	52.00	51.13	36.27	43.99	53.96	54.90	50.83	43.73	47.28
(133 x 107)	38.30	40.05	39.62	47.62	33.89	34.00	41.73	44.93	36.10	37.03	40.68	46.28	41.40	38.64	40.02
(151 x 153)	53.74	51.79	53.84	48.50	31.41	55.53	58.39	60.96	42.58	53.66	56.12	54.73	51.97	51.57	51.77
(130 x 107)	34.15	45.27	48.46	62.07	20.21	40.73	43.94	48.42	27.18	43.00	46.20	55.24	47.49	38.33	42.91
Minnesota No. 13	46.54	39.54	51.82	53.89	31.56	24.79	47.50	54.23	39.05	32.17	49.66	54.06	47.95	39.52	43.73
Means	41.02	43.25	48.01	51.41	26.52	38.44	45.35	47.83	33.78	40.85	46.68	49.62	45.92	39.54	42.73

Necessary difference for significance (bus. per acre)		Means	Single Plots	Means	Single Plots	Means	Single Plots	Means
	P = .05	6.11	18.33	4.32	12.96	3.05	9.16	6.48
	P = .01	8.03	24.08	5.68	17.04	4.01	12.04	8.51

1942.—Yields in bushels of shelled corn per acre (absolute dry weight)

Hybrid or Variety	Average kernel moisture at harvest (%)											
	48.9	*41.2*	*30.5*	*20.3*	*48.9*	*41.2*	*30.5*	*20.3*	*48.9*	*41.2*	*30.5*	*20.3*
	Replicate 1				Replicate 2				Replicate 3			
	bus.	bus.	bus.	bus.	bus.	bus.	bus.	bus.	bus.	bus.	bus.	bus.
	AIR DRIED											
(153 x 150) (148 x 151)	94.26	94.98	85.62	90.66	86.15	86.97	90.35	78.86	71.63	59.14	55.55	64.66
(116 x 113) (125 x 117)	61.39	51.20	61.26	74.95	75.76	62.09	68.59	80.77	70.03	61.25	60.86	75.05
(131 x 107) (38 x 37)	66.90	74.31	72.47	64.25	58.87	62.23	45.56	56.24	74.12	58.00	66.28	65.78
(129 x 131) (125 x 117)	54.93	77.05	72.37	99.53	68.34	64.20	66.67	90.70	74.96	71.80	76.64	89.80
(152 x 131) (134 x 133)	79.16	67.50	87.92	102.26	47.72	47.92	76.65	93.27	76.09	74.33	84.47	69.47
(133 x 107)	57.36	64.12	61.79	71.38	60.83	43.46	54.33	54.66	51.85	37.98	50.51	47.06
(151 x 153)	80.14	67.38	75.11	90.96	96.54	77.71	94.12	107.20	79.93	75.17	88.47	101.63
(130 x 107)	62.67	64.35	69.94	77.19	58.53	67.50	71.12	71.69	30.30	55.24	44.03	68.01
Minnesota No. 13	61.71	71.46	71.20	75.01	69.07	66.51	76.47	92.73	83.69	73.95	88.79	100.01
	Artificially Dried, 108° F.											
(153 x 150) (148 x 151)	61.78	79.04	72.07	90.96	80.22	76.44	84.37	75.08	57.24	74.02	80.21	70.09
(116 x 113) (125 x 117)	51.65	56.34	50.61	62.01	21.58	58.12	89.17	85.89	33.27	69.94	86.75	91.01
(131 x 107) (38 x 37)	60.76	67.74	69.36	71.46	47.33	65.25	72.98	63.48	68.37	54.15	73.42	69.73
(129 x 131) (125 x 117)	4.12	75.81	67.98	74.53	2.85	54.86	73.18	64.59	11.58	48.15	83.24	71.64
(152 x 131) (134 x 133)	35.43	85.46	78.95	73.07	12.77	39.03	88.78	66.20	41.56	65.95	78.24	61.64
(133 x 107)	44.03	44.40	64.21	49.94	18.18	28.79	61.39	60.80	34.42	40.14	54.58	75.17
(151 x 153)	50.48	89.99	84.09	87.06	15.73	100.51	103.09	82.81	54.09	95.15	92.48	95.22
(130 x 107)	4.62	46.85	70.52	68.35	7.69	17.55	51.87	70.01	13.15	46.84	67.66	65.16
Minnesota No. 13	4.24	30.69	78.08	67.90	18.25	27.52	68.88	75.35	8.46	22.40	76.50	70.44

ANALYSIS OF VARIANCE

	Due to	S S	D F	M S	F	F value for 5%	F value for 1%
	Methods of Treatment	7757.2920	1	7757.2920	33.00	3.89	6.76
	% Moisture at Harvest	22334.8830	3	7444.9610	31.67	2.65	3.88
	Varieties	19769.4272	8	2471.1784	10.51	1.98	2.60
(A)	Replicates	374.4262	2	187.2131	1.26	19.49	99.49
	Error (1)	47252.9690	201	235.0894			
	Interaction methods x moistures	12133.0253	3	4044.3418	38.46	2.67	3.91
	" methods x varieties	5443.0207	8	680.3776	6.47	2.00	2.62
	" moisture x varieties	8839.2569	24	368.3024	3.50	1.59	1.91
	" method x replicates	538.2952	2	269.1476	2.56	3.06	4.75
(B)	" moisture x replicates	818.3435	6	136.3906	1.30	2.16	2.92
	" varieties x replicates	4550.2669	16	284.3917	2.70	1.71	2.12
	Error (2)	14930.7605	142	105.1462			

1942.—Mean yields in bushels of shelled corn per acre (absolute dry weight)

Hybrid or Variety	Air Dried				Artificially Dried				Air Dried and Artificially Dried				Air Dried	Artificially Dried	General Mean
	Average kernel moisture at harvest (%)												All Moistures		
	48.9	*41.2*	*30.5*	*20.3*	*48.9*	*41.2*	*30.5*	*20.3*	*48.9*	*41.2*	*30.5*	*20.3*			
(153 x 150) (148 x 151)	84.01	80.36	77.17	78.06	66.41	76.50	78.88	78.71	75.21	78.43	78.03	78.39	79.90	75.13	77.51
(116 x 113) (125 x 117)	69.06	58.18	63.57	76.93	35.50	61.47	75.51	79.64	52.28	59.82	69.54	78.28	66.94	63.03	64.98
(131 x 107) (38 x 37)	66.63	64.85	61.44	62.09	58.82	62.38	71.92	68.22	62.73	63.61	66.68	65.16	63.75	65.34	64.54
(129 x 131) (125 x 117)	66.08	71.02	71.89	93.34	6.18	59.61	74.80	70.25	36.13	65.31	73.35	81.80	75.58	52.71	64.15
(152 x 131) (134 x 133)	67.66	63.25	83.01	88.33	29.92	63.48	81.99	66.97	48.79	63.37	82.50	77.65	75.56	60.59	68.08
(133 x 107)	56.68	48.52	55.54	57.70	32.21	37.78	60.06	61.97	44.45	43.15	57.80	59.84	54.61	48.00	51.31
(151 x 153)	85.54	73.42	85.90	99.93	40.10	95.22	93.22	88.36	62.82	84.32	89.56	94.15	86.20	79.23	82.71
(130 x 107)	50.50	62.36	61.70	72.30	8.49	37.08	63.35	67.84	29.49	49.72	62.52	70.07	61.71	44.19	52.95
Minnesota No. 13	71.49	70.64	78.82	89.25	10.32	26.87	74.49	71.23	40.90	48.76	76.65	80.24	77.55	45.73	61.64
Means	68.63	65.84	71.01	79.77	31.99	57.82	74.91	72.58	50.31	61.83	72.96	76.17	71.31	59.33	65.32

Necessary difference for significance (bus. per acre)		Means	Single Plots	Means	Single Plots	Means	Single Plots	Means
	P = .05	8.18	24.54	5.78	17.35	4.09	12.27	8.67
	P = .01	10.75	32.25	7.60	22.80	5.37	16.12	11.40

OTTAWA
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